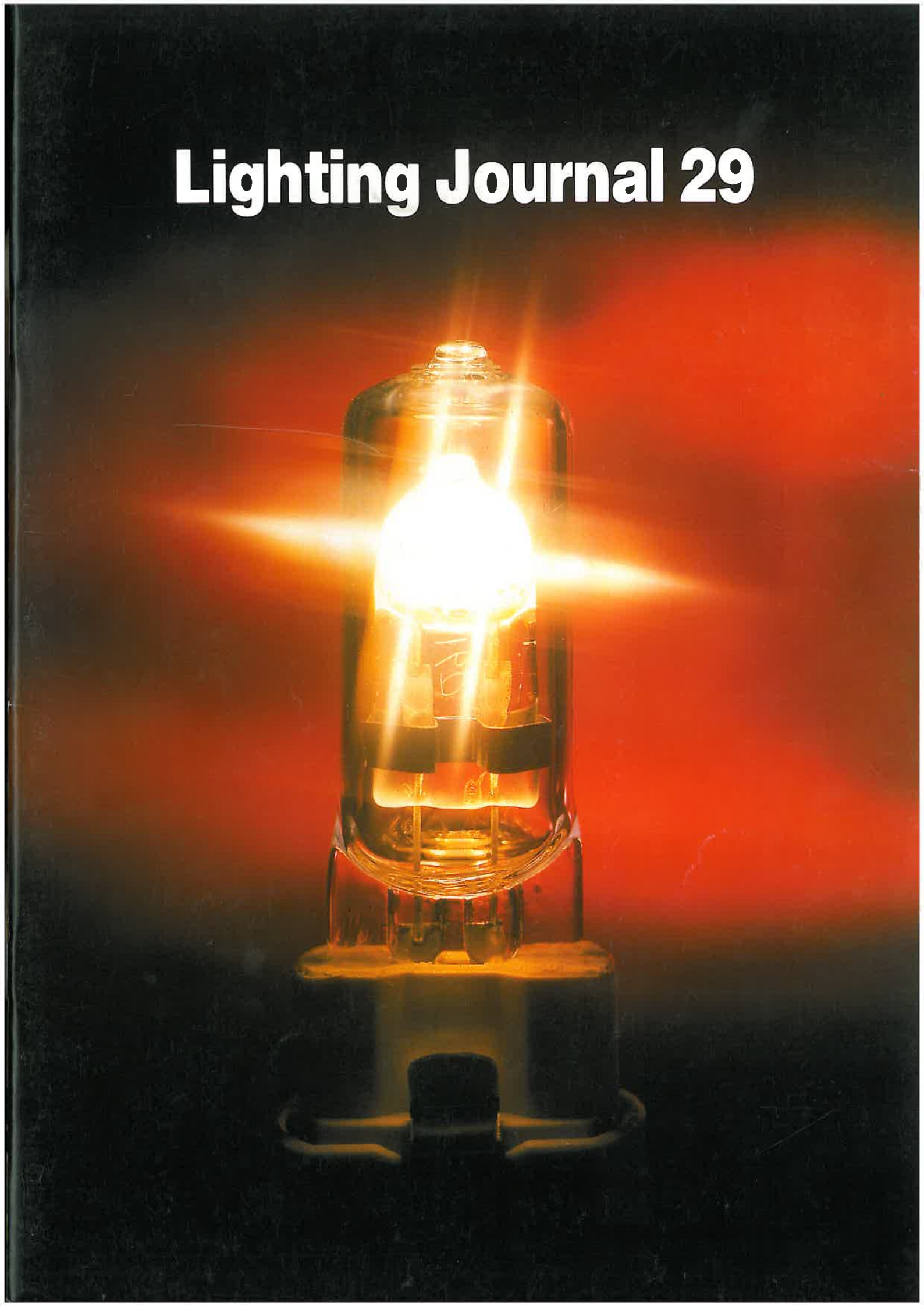
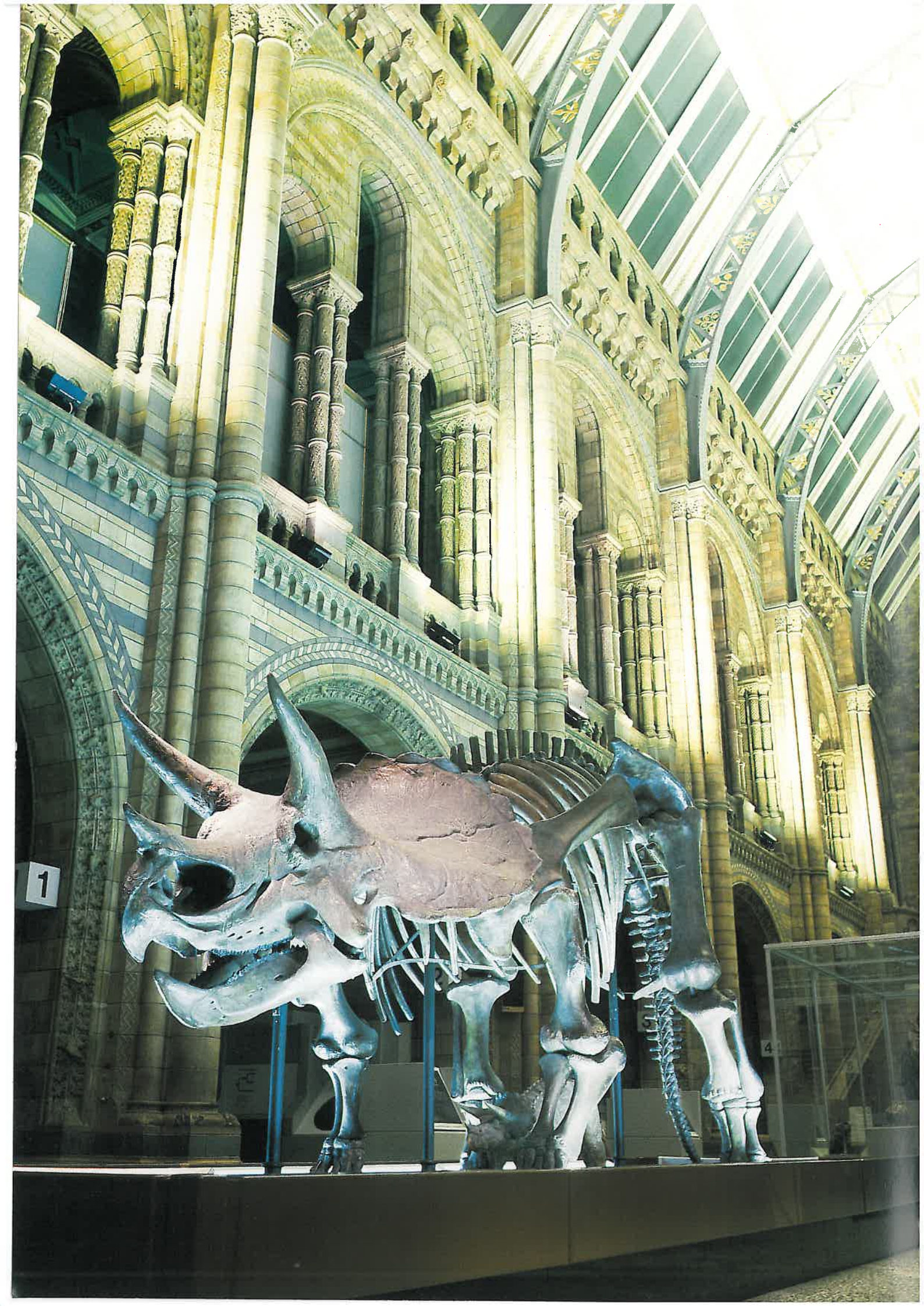
Lighting Journal 29





Lighting Journal 29

Summer 1988

Front cover: **Close up of a single ended 150W metal halide lamp after the arc has struck.**

Back cover: **British Steel Corporation's Moss Bay works in Workington — where railway lines are manufactured for British Rail's 125 Inter City network and for over 30 countries worldwide — has been given the high pressure sodium lighting treatment. Discharge luminaires have been used throughout the plant in a massive ongoing programme to improve the quality of light and save on energy costs. For rail inspection a high illuminance of 1000 lux is provided by 1kW luminaires enabling the work to be carried out indoors — the only plant in the world able to do so.**

Inside front cover: **The ancient, the Victorian and the modern blend to stunning effect in the lighting scheme at the Natural History Museum's dinosaur hall. 400W high pressure sodium and 1000W tungsten halogen lamps are placed alternately in OWS floodlights in uplight mode. The pleasing mix of 'golden' and 'white' lamps blend subtle colour tones to the replicas of the 70 million year old Triceratops dinosaur. As dramatic detail is revealed in the exhibits, so the grandeur of the hall with its beautifully painted arched ceiling of horticultural scenes, is brought vividly to life.**

Inside back cover: **High pressure sodium floodlights with low glare louvres are cutting costs and providing a more pleasant atmosphere for the Fleet Air Arm Museum, Yeovilton in Somerset. The Concorde hangar, which houses the famous 002 prototype was lit originally with track mounted 300W PAR 56 spotlights. The new scheme uses fourteen 400W and five 250W SON-TD floodlights. Electrical load has been reduced from 26kW to 7.5kW.**

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Lamp technology is the life blood for the future growth of any major lighting company, but equally, knowledge and flair in its application is the sustenance to the company's existence. Therefore, in this issue of the Lighting Journal, we concentrate not only on new light source identification but also demonstrate examples of what constitutes modern lighting practice.

The potential in low wattage metal halide has prompted the development of Arcstream, a new, compact 150W lamp. It is specifically designed to provide high quality light for commercial interiors and external floodlighting. This is followed by a report on the first ever National Lighting Awards which demonstrate beyond doubt that correct lighting levels can be achieved at no expense to aesthetic sensitivity. The detailed case studies illustrate both excellence and innovation in lighting design, and it is interesting to note the use of the high pressure sodium lamp continues in its diversity.

The trend towards the integration of lighting and ventilation, greater use of electronic control gear and yet more sophisticated optical control continues. With this subject as a theme we determine the effect this emphasis is having on fittings manufacturing and design techniques and how this will benefit the final customer. From there the complexities of lighting systems for tunnels, frequently underestimated, are examined. Road tunnels vary; in dimensions, construction or usage, but modern luminaires encompassing the latest advancements in technology provide a solution for each with high efficacy, easy maintenance and economy of performance.

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R C Aldworth, R I Bell
M A Cayless, R Forster, H R King,
W Milford

Our substantial worldwide business activities are reviewed in this issue, highlighting the diversity and often highly impressive nature of the applications undertaken, and the technical service package offered.

Finally we go to Inverness to glimpse the stark beauty of Fort George enhanced by a creative but sympathetic lighting scheme. One of the most outstanding artillery forts in Europe, refurbishment has taken three years and involved a complete redesign and installation of the entire electrical system.

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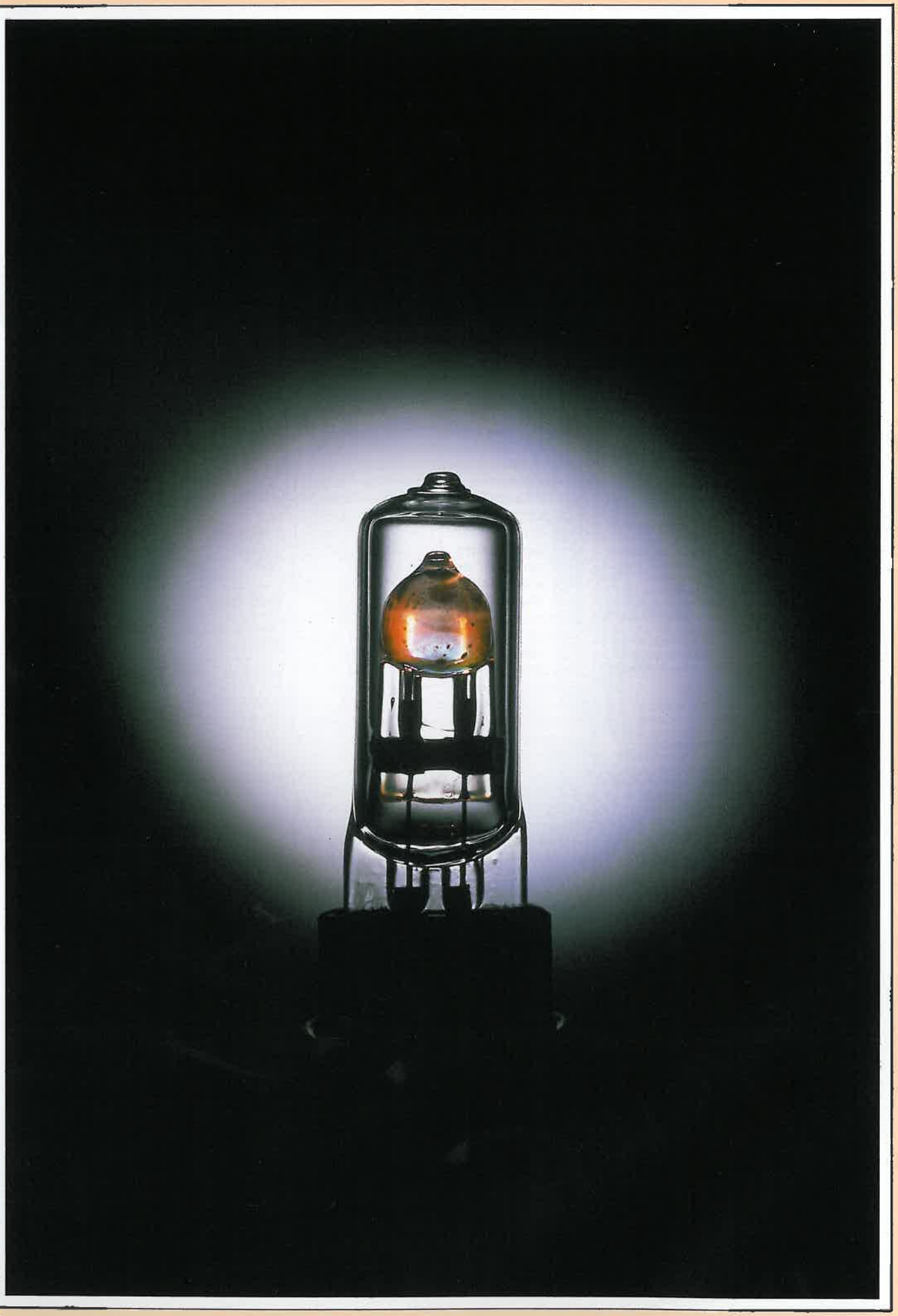


BOB HALL

The Technology of Arcstream

Dr Hall is Technical Manager of THORN Lighting Discharge Lamp Division at Leicester

Over the past three years, a team from the Leicester laboratories has been working on a development which is about to bring the metal halide discharge lamp (MBI) back into the central arena of lighting. To date, MBI has been seen as a superb specialist source for applications where superior colour performance is a paramount requirement, but wider acceptance has been limited.

Several factors account for this. Metal halide was not generally available in wattages below 250W. It is difficult to produce a small halide lamp in which colour performance does not degrade with burning hours. Lamp life has been limited, at least against the yardstick of expectations created by the high pressure sodium lamp. Doubled ended MBI lamps can limit the design options and incur cost penalties for fittings. Such lamps also dictate horizontal burning, reducing flexibility in application. Another inhibiting factor has been lack of standardisation of sockets and control gear.

LOW WATTAGE METAL HALIDE

An extension to the MBI range is a 150W lamp, recently launched as Arcstream. Further developments are aimed at 70W and probably lower ratings so that evolution of a new range of metal halide sources providing high quality white light will extend the market application of discharge lamps. Arcstream provides the excellent colour characteristics of metal halide in a package which combines compact convenience with high efficacy and economy when operating on conventional control gear. Arcstream is the solution to those factors which have previously constrained the acceptance of MBI.

DESIGN PHILOSOPHY

The team was able to draw on the technology which underpins 'standard' MBI sources and particularly the range of single pinch metal halide lamps which THORN Lighting has been offering for over 20 years for studio environments. It was clear that lamp life would have to be extended from the three hundred hours typical of the lower wattage CID lamps. The required improvement was accomplished by enclosing the silica arc tube inside an evacuated outer envelope, also of silica. The enclosure excludes air and moisture, and also makes the lamp more robust. In the case of CSI and CID lamps a similar increase in life is achieved when the arc tubes are sealed into the PAR 64 reflectors.

Making the lamp single ended confers several advantages. Luminaire ▶

On the opposite page is a close up of an Arcstream lamp immediately after the arc has struck and below the lamp compared with a 150W SON-T light source.

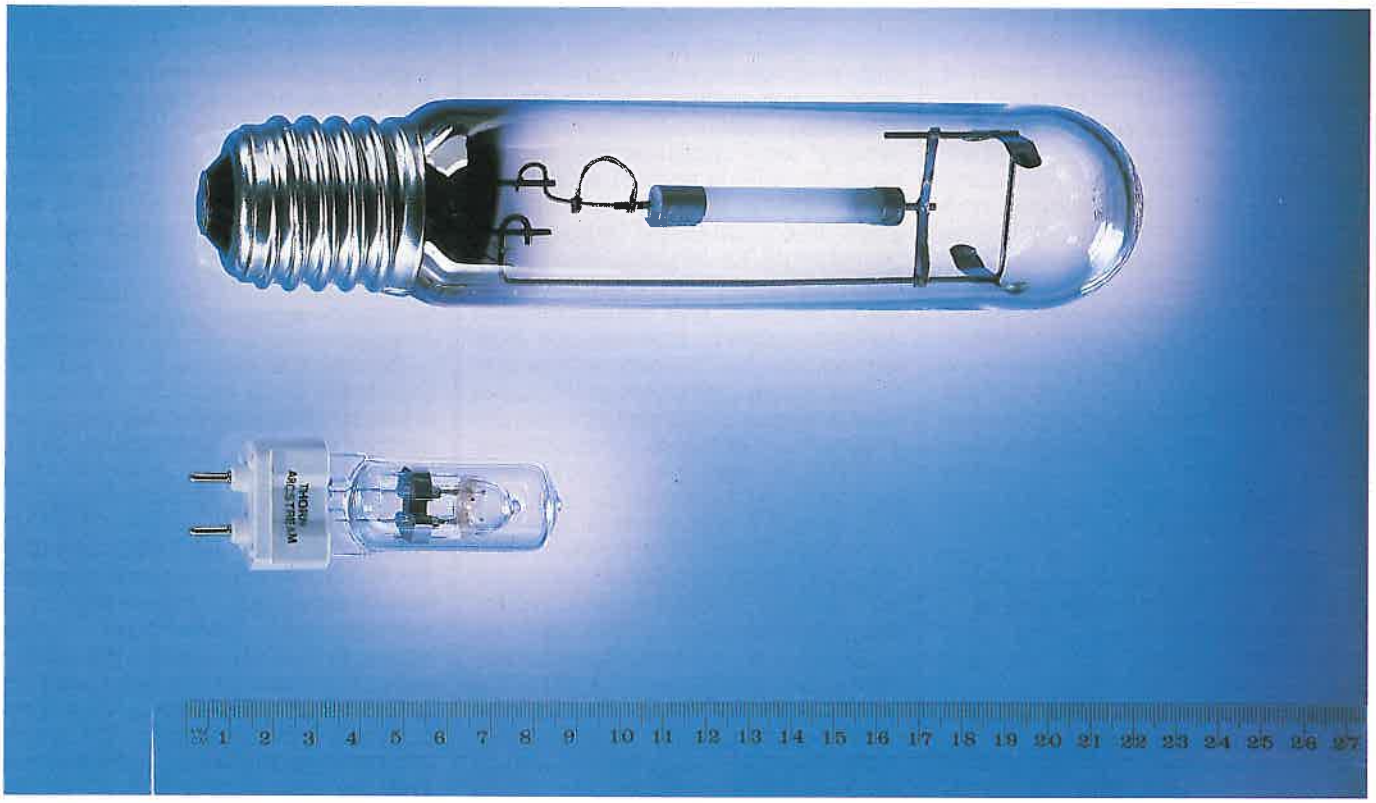
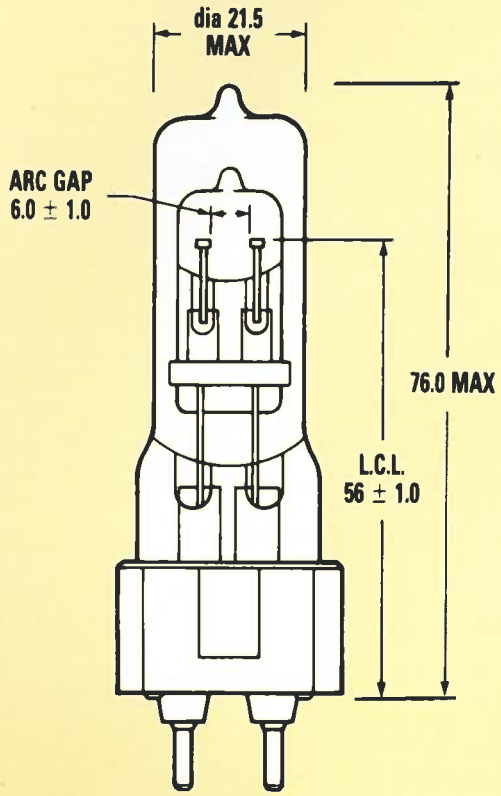


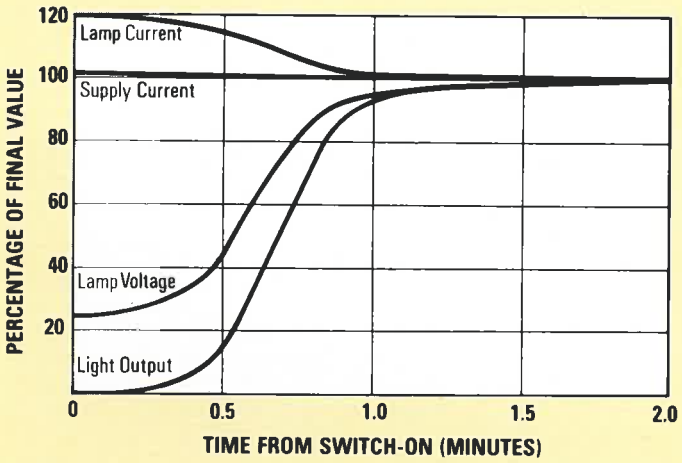
Fig 1



All dimensions mm

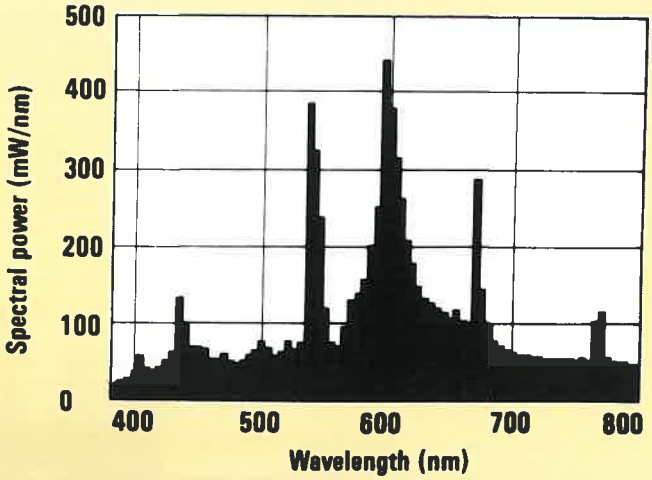
RUN UP CHARACTERISTICS

Fig 3



SPECTRAL DISTRIBUTION

Fig 2



Above Fig 1 details exact dimensions and on the right Fig 2 shows the spectral distribution. Top right Fig 3 illustrates run up characteristics.

design is simplified and fittings can be made more compact. Close control of beam shape is easier to achieve. The lamp is suitable for universal burning, adding to its potential range of applications in suitably designed luminaires.

The G12 socket was selected both for this lamp and for future extensions. Moreover, other manufacturers engaged in parallel developments have adopted the same socket, so that G12 is already a 'standard' for low wattage metal halide. This will promote interchangeability between ratings and among the low wattage metal halide products of different manufacturers. Similarly, a single, high energy electronic ignitor has been developed for the entire projected Arcstream range.

The design philosophy has resulted in a powerful lumen package which is nevertheless compact, durable, tolerant and can be used with confidence in a wide range of applications.

LAMP CONSTRUCTION

The basis of Arcstream, is a metal halide discharge operating at very high pressure in a silica arc tube. A single pinch positions the electrodes 6mm apart, making for an extremely compact arc. Figure 1 shows just how small the 150W lamp is. The new lamp is compared to the 150W de luxe high pressure sodium (SONDL) lamp, both providing 12,000 lumens.

The arc tube is filled with a combination of mercury with sodium, tin and thallium halides, selected for high spectral quality. The lamp will be produced in two versions providing a choice of colour temperature – initially a warm white with a colour temperature of 3000K, followed later this year by an intermediate white at 4000K.

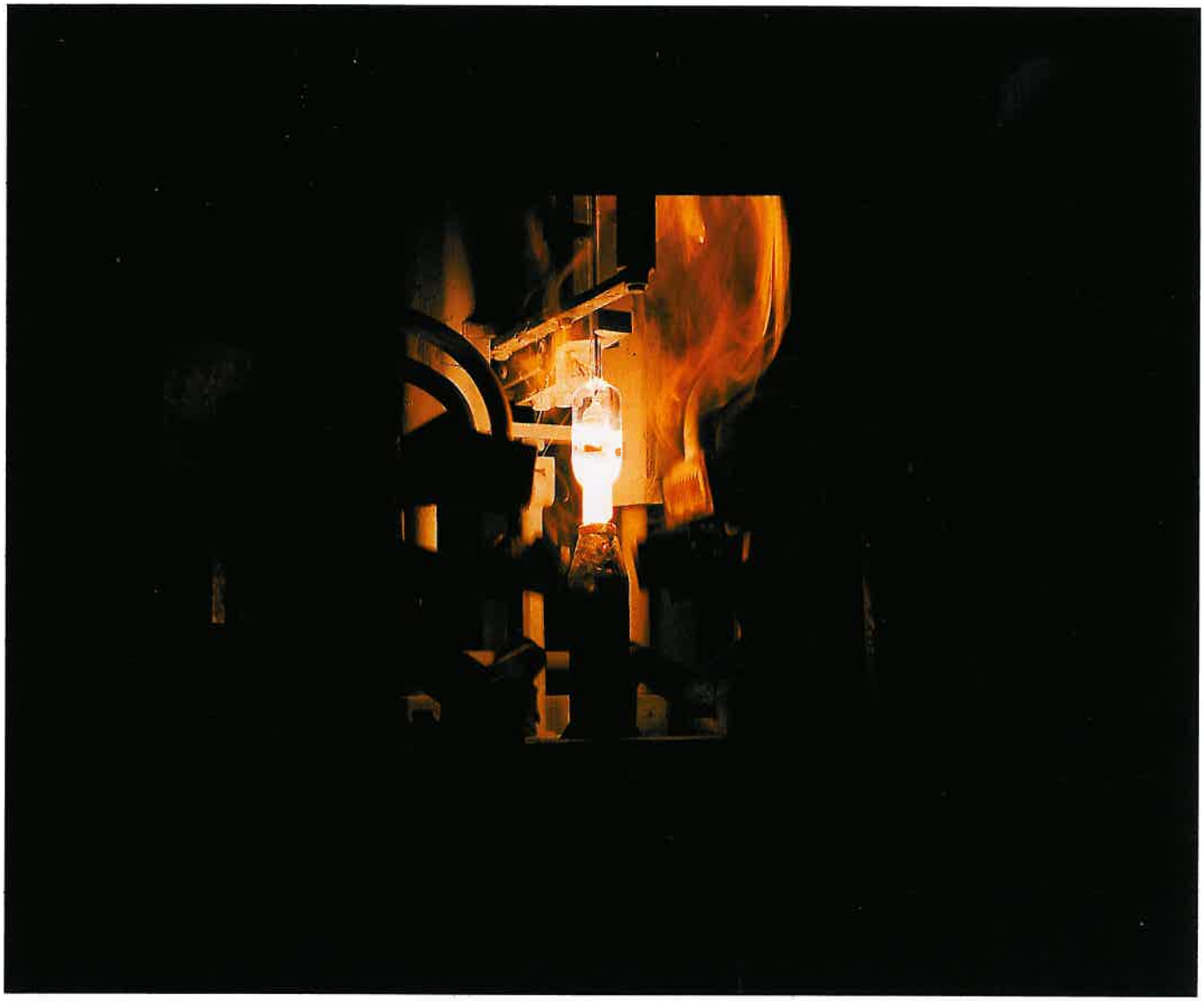
To ensure a high safety factor at the very high operating pressures, each arc tube is fully pressure tested during manufacture. A reliable pinch assembly which can sustain this pressure indefinitely is essential. The silica-to-metal seal is engineered by making the silica flow uniformly round a pair of thin foils of molybdenum, forming part of the electrode pin assembly. The foils are feathered, having twin outer edges and thicker centres, with a smoothly curved profile to ensure freedom from local stresses in the bonded layer of silica.

The light source has a silica outer jacket to achieve the average lamp life of 6000 hours, equivalent to two years of operation in a typical display lighting application.

PERFORMANCE

The spectral distribution of a 150W Arcstream lamp provides excellent colour rendering properties due to the continuity of the spectrum resulting from the rich molecular radiation of the metallic halides selected (see figure 2). The general colour rendering index, (Ra), is 80 for both the 3000K lamp and the 4000K version, making Arcstream lamps Group 1 (b) under the DIN 5035 classification. Conventional metal halide lamps by comparison have colour rendering indices of around 70.

Arcstream can be operated in any position with colour appearance remaining consistently good irrespective of lamp orientation. This is



A close up view of one of the stages in the manufacture of the Arcstream lamp at Leicester.

achieved by having a spherical arc tube, so avoiding pockets in which iodide constituents might collect separately to spoil the colour balance. Colour stability through life is within ± 200K, about three times better than that achieved by earlier metal halide designs.

The high luminous efficacy of 80 lm/W is combined with excellent lumen maintenance. After 2,000 hours the lamp still supplies 10,000 lumens, compared with 12,000 lumens after 100 hours. This 80% lumen maintenance is associated with the familiar tungsten halogen cycle, which inhibits tungsten evaporated from the electrodes being deposited on the walls of the arc tube which would attenuate the light output.

ELECTRICAL CHARACTERISTICS

The 150W Arcstream lamp is designed to operate on a conventional discharge ballast and ignitor circuit. Low wattage metal halide lamps are sensitive to variations in the mains supply and for best life, lumen maintenance and colour uniformity, a ballast must be chosen which has a voltage tapping within ±3% of the mean supply voltage. Voltage supply excursions of 5% are tolerable, for short periods, provided that for the majority of its life the lamp is not over-run.

MBI lamps require high energy impulses for starting. High voltage is needed initially to ionise the arc tube contents, then high energy is required to transform the initial 'glow' to a full arc. A new THORN electronic ignitor has therefore been developed which provides 4kV pulses each mains half cycle to ensure rapid and reliable starting.

The transient characteristics of the lamp from a cold start with the recommended ballast are shown in figure 3. It can be seen that Arcstream attains half of its light output within a few seconds and 90% of full lumen output within a minute. The lamp will restart after having been switched off in about four minutes.

QUALITY CONTROL IN MANUFACTURE

The quality and performance of Arcstream depend as much on refined manufacturing technology as on the lamp's design. To form the hemispherical outer end of the arc tube repeatably requires closely integrated control of flame temperatures as the shape is formed from the end of a piece of silica tube. The seal at the other end has been specified after considerable development effort in refining the well established pinch seal process. One hundred per cent inspection monitors pinch quality, ensuring that air bubbles or microcracks do not prejudice the life expectancy of the lamp.

A major enemy of success is moisture, which must be kept down to a level less than five parts per million inside the arc tube. To this end the electrode assembly is vacuum baked before it is introduced into the tube. The halides are inserted into the arc tube inside a dry box; indeed environmental conditions are carefully controlled throughout the entire production sequence. Finally the arc tube is mounted within the outer silica envelope and the G12 cap is then attached.

Finished lamps are subjected to a starting test with reference ballasts and ignitors; any which do not start at ▶

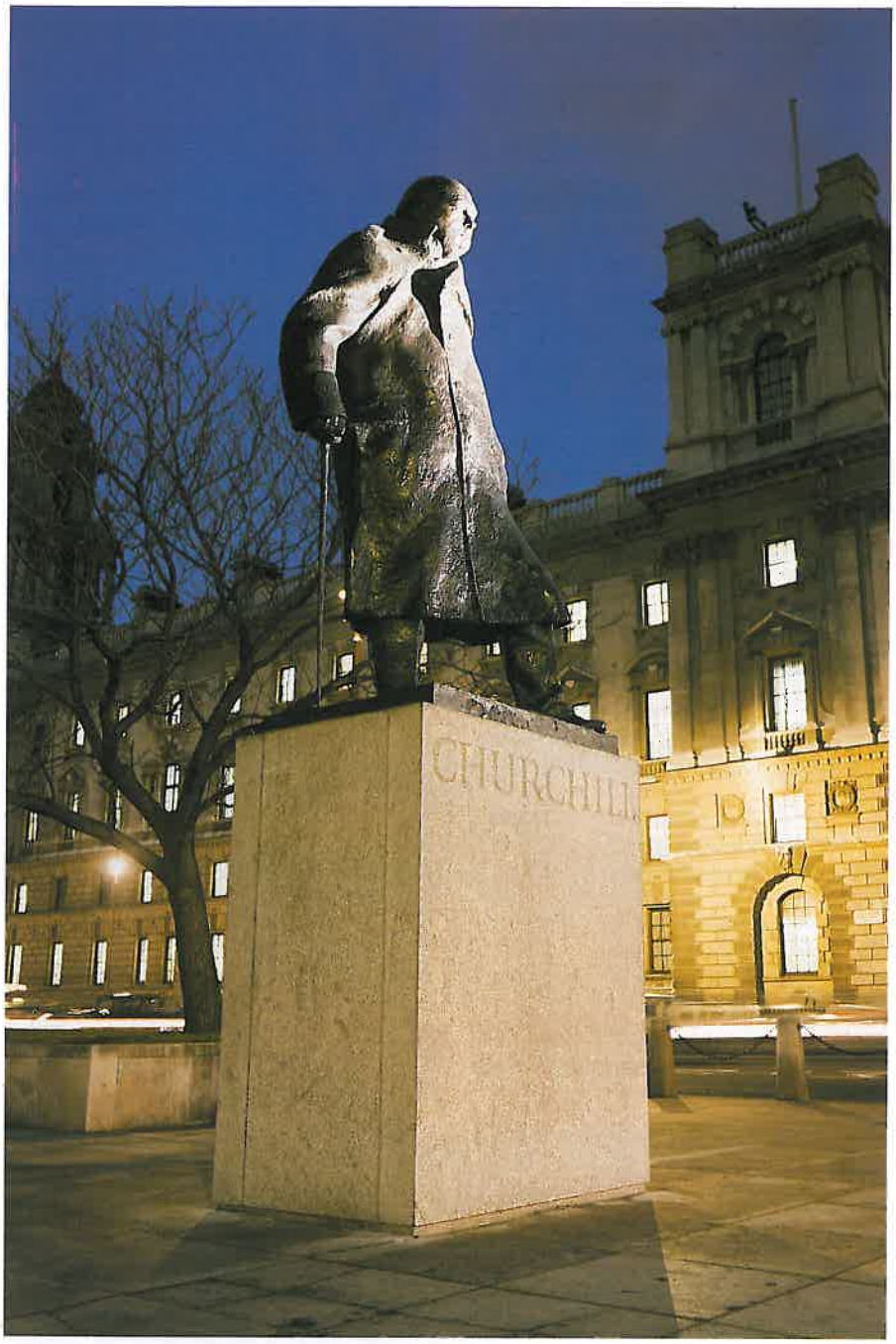
Left and below: **The magnificent Main Hall of the Royal Museum of Scotland in Edinburgh, uses Arcstream lamps housed in specially designed quarter sphere uplights along the second floor balcony. The resulting pools of white light serve to enhance the detail of the birdcage structure of the glass and iron roof.**

In addition low voltage luminaires feature strongly in the scheme.

The new lighting provides a reduction in electrical load to 16.8kW, compared to 20.4kW in the previous fluorescent and PAR 38 scheme. Equally, illuminance levels have risen from 25 to 110 lux.

Refurbishment of the lighting forms part of a restoration programme by the PSA. Constructed in 1861-1885, the design influenced by London's Crystal Palace, the Main Hall is the centre piece of one of Scotland's finest tourist attractions and its largest Grade A listed building.

Right: **The versatile Arcstream light source is equally at home for exterior lighting. Shown is just one floodlight creating excellent modelling for the Churchill Statue in Parliament Square, London.**



198v are rejected. They are also checked for colour, electrical and luminous performance.

APPLICATIONS

Because Arcstream is compact, economical, efficient, and provides high quality white light, it is well suited to commercial interiors and display lighting. The 3000K version blends well with low voltage tungsten halogen lamps providing a complementary higher output package for display lighting. A single 150W lamp has an output at least ten times that of a 50W 12v tungsten halogen lamp and lasts twice as long. This will make it ideal for retail, exhibition and other display applications where powerful lighting is required with unobtrusive sources.

Arcstream also makes a highly suitable alternative for PAR lamps, providing five times the output of a normal PAR lamp of similar power. It can be used in downlighters, reducing the number of luminaires required where there are high ceilings. The lamp will extend the flexibility of uplight schemes by making smaller, more elegant fittings which will add to the attraction of uplighting for commercial interiors, extending the use of this lighting technique into areas beyond the functional office environment.

With its universal burning capability and compact single ended form, Arcstream is a boon to luminaire designers. Accurate beam control can be obtained from quite small parabolic reflectors, either faceted or textured to spread the illumination. Out of doors, these features will also extend the scope for floodlighting. The compact source lends itself to close optical control and new fittings will certainly be designed to compete with tungsten halogen for high intensity narrow beam applications.

In the design of fittings for these lamps it is necessary to use a front cover glass that is ultraviolet absorbent because the lamp emits UVB and to a lesser extent UVA. In addition this guards against the unlikely event of a tube shattering on failure.

CONCLUSION

This Arcstream introduction heralds the start of a new era of high quality discharge lighting. This family of low wattage lamps will extend the applications of metal halide to a much wider market. The ability to control the output to reveal texture will put excitement and interest back into lighting. Perhaps this is the beginning of the end of the fluorescent tube as the automatic choice for commercial lighting.

NATIONAL LIGHTING AWARDS

The National Lighting Awards is a new competition which commends excellence and innovation in the design of lighting. The scheme is organised by the Lighting Industry Federation and comprises four key sections; Industrial, Commercial, Leisure and Civic. Virtually all types of lighting are included except for road and domestic illumination. Co-sponsors include the Design Council, Society of Industrial Artists and Designers, the Electricity Council and leading electrical trade bodies.

When design minister John Butcher announced the results, THORN Lighting installations had won three of the four sections with three other schemes receiving commended citations.

THE AWARDS

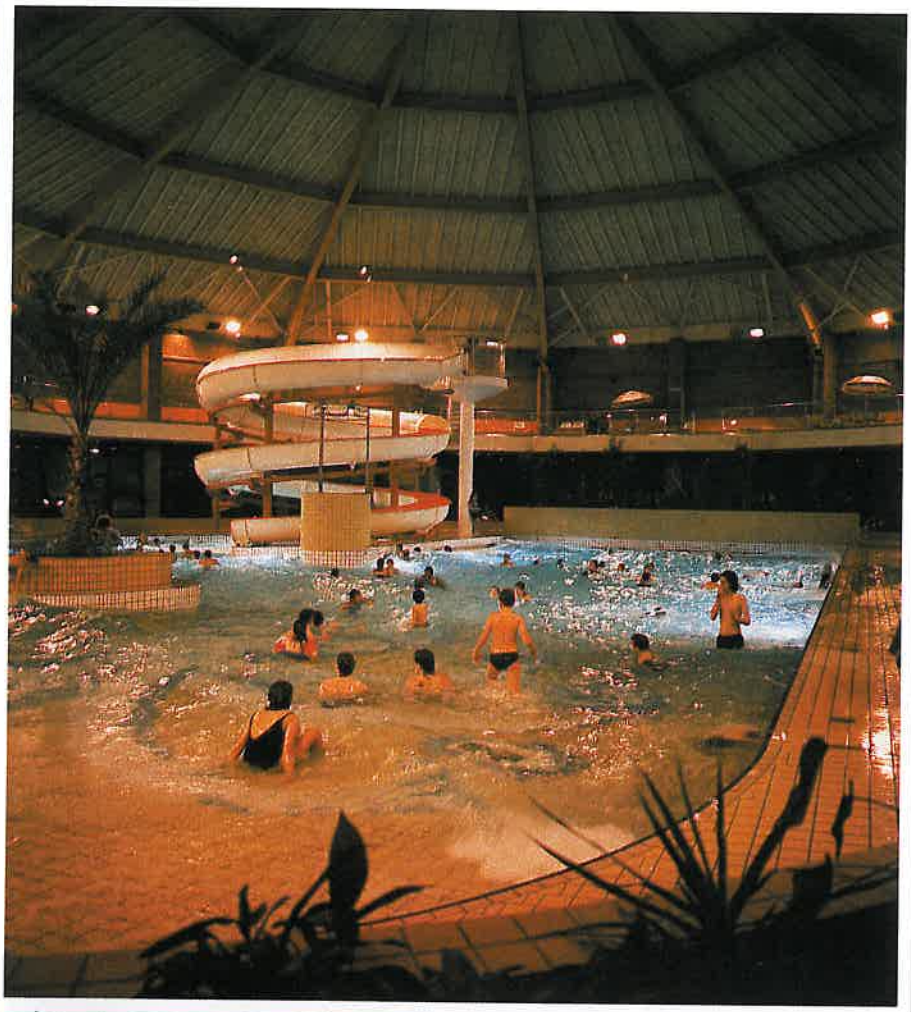
Winner, Industrial section

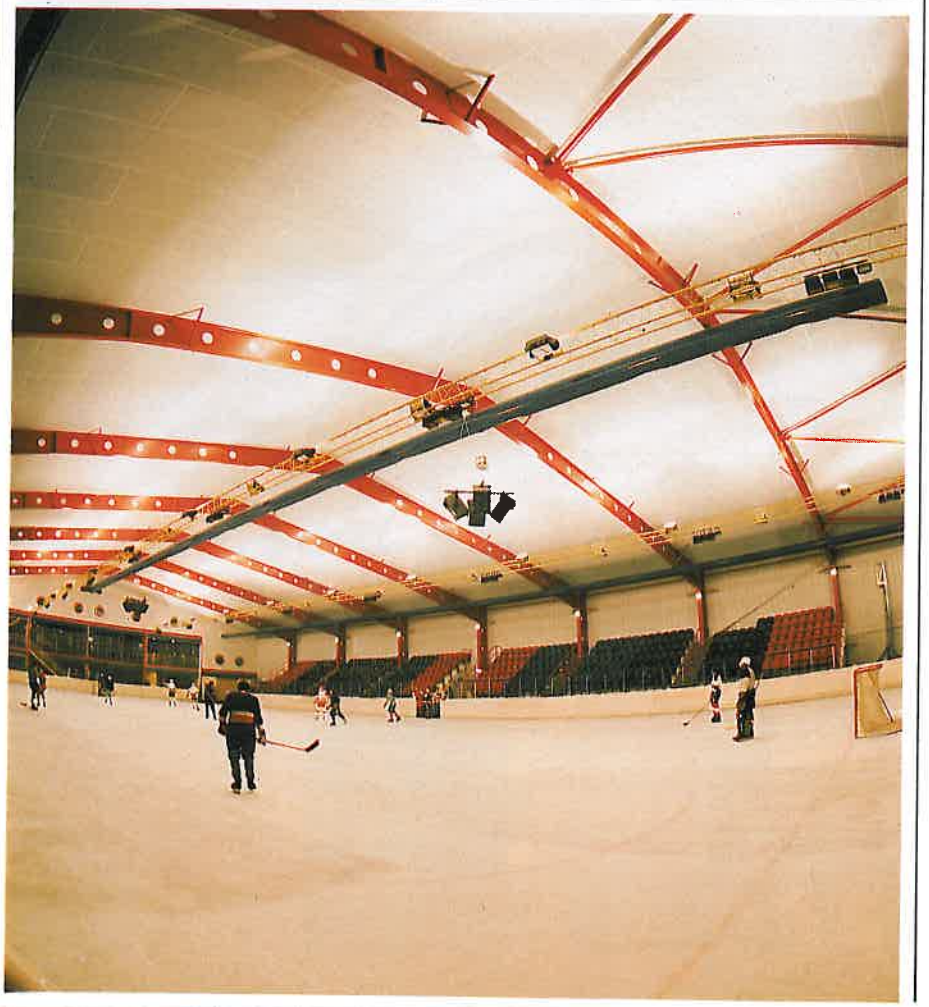
ELECTROLUX

Spennymoor

This factory, manufacturing modern cookers, won the Industrial section. When the Company decided to refurbish the site, a comfortable and controlled working environment was the priority and a move away from the traditional image of unsightly, multi-lamp fluorescent luminaires was sought. Now lit by 570 unobtrusive Radpak luminaires housing low energy 250W de luxe high pressure sodium lamps (SONDL), the result is the most up to date cooker factory in Europe. The radial batwing distribution provided by the luminaires is ideal for symmetrical spacing, enabling uniform lighting of 600 lux with good glare control and correct vertical illuminance to be achieved. Electrical load is a mere 158kW and good colour rendering allows employees to differentiate between production components of various colours and sizes. The lighting has contributed to a new standard of working environment in creating a warm, airy and inviting atmosphere.

Design: D Stallworthy, THORN Lighting
Architect: Duncan Biggin Partnership, Leeds
Contractor: TGF Electrical





Winner, Leisure Section

NEWPORT LEISURE CENTRE

Newport

The brief stated that swimmers must be visible at all times and that it was important to vary the mood of the lighting to cater for fashion spectaculars and private pool parties etc. General lighting is achieved by 40 wall mounted Area floodlights, using 400W SONDL lamps. Average horizontal illuminance across the water surface is 546 lux while half of the floods use black transverse louvres to minimise direct glare. Wall washing of the fascia brickwork enclosing the pool is met by 32 low power 200W linear tungsten halogen floodlights. Decorative pool colour effects are provided by 500W tungsten halogen spotlights and 14 special underwater porthole luminaires with 400W MBIF mercury Kolorarc lamps.

Design:	L Mower, F A Barton Lawrence and Partners and R Phipps, THORN Lighting
Architect:	B Wyld, Newport Borough Council
Contractor:	Matthew Hall

Highly Commended, Leisure Section

THE ICE BOWL

Gillingham

The installation gives very low glare and great flexibility by using stadia floodlights in uplight mode. Thirty eight 400W SONDL units are mounted on two suspended booms running the length of the hi-tech stadium. A service illuminance of 400 lux is provided for an electrical load of 16.6kW. In addition 500W tungsten halogen floods with colour filters provide attractive downward light for ice shows and disco type events.

Design:	N Farraway, THORN Lighting
Architect:	Sports and Leisure Developments
Contractor:	Client

Winner, Commercial Section

PETERBOROUGH DATA PROCESSING SERVICES

Peterborough

In the new, open plan offices, made comfortable for employees by low level glazing and a striking exposed roof structure, 135 uplights contribute by providing over 500 lux of glare-free illumination. To meet the requirements of VDUs and the need to blend in with natural daylight THORN Lighting produced a special uplight, housing a mixture of 250W metal halide and SONDL lamps. The SONDL lamps are kept permanently on with a solar time controller switching on the metal halide light sources when daylight falls below a pre-set level. Seventy of these unique wall mounted units ensure that the contrast between day and night operation is reduced to a minimum. In addition 65 stylish, freestanding 250W SONDL uplights ensure maximum flexibility within the office space. The uplights highlight perfectly the angular, natural wood lines of the interior roof. Circulation routes are lit with recessed 16W 2D downlights.

Design: The Dyer Warner Partnership, Leicester with A Coldrick and R Phipps THORN Lighting
Architect: Jefferson Sheard and Partners, Sheffield
Consultants: Colin Brooks Associates
Contractor: T Clarke (Midlands)

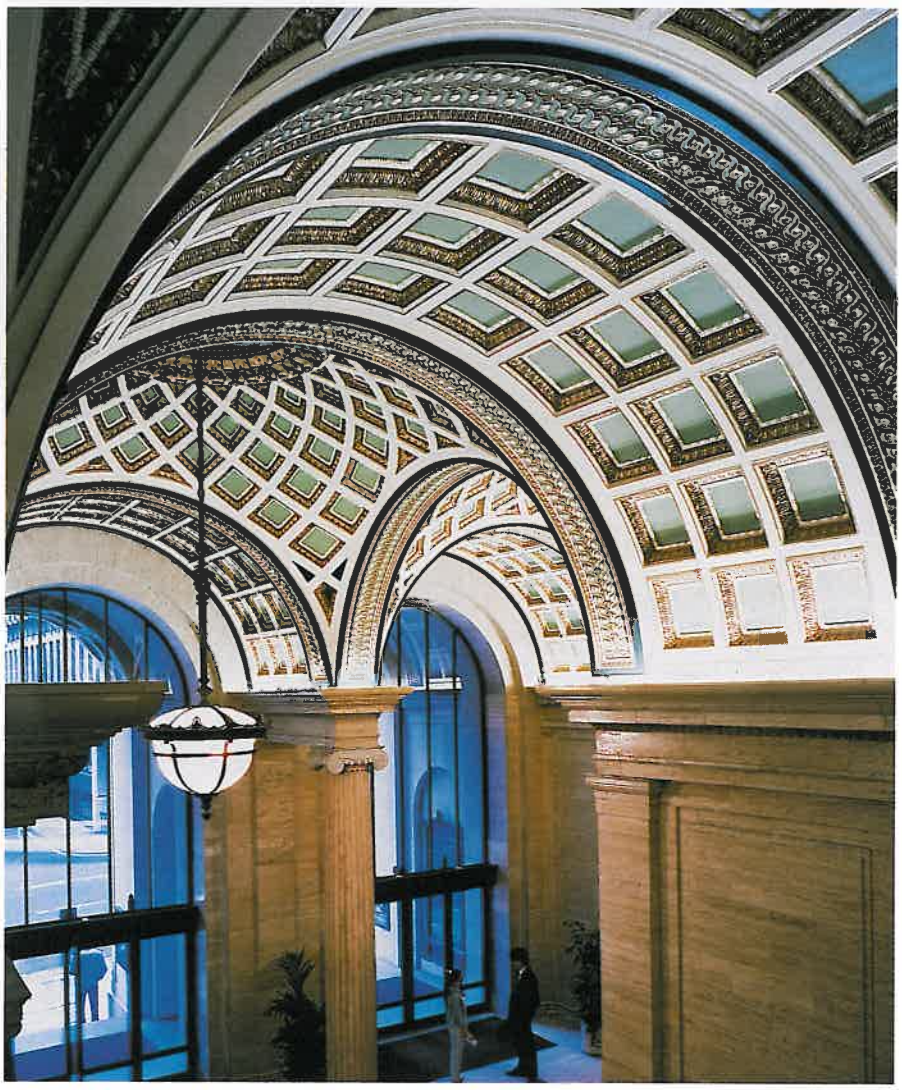
Commended, Commercial Section

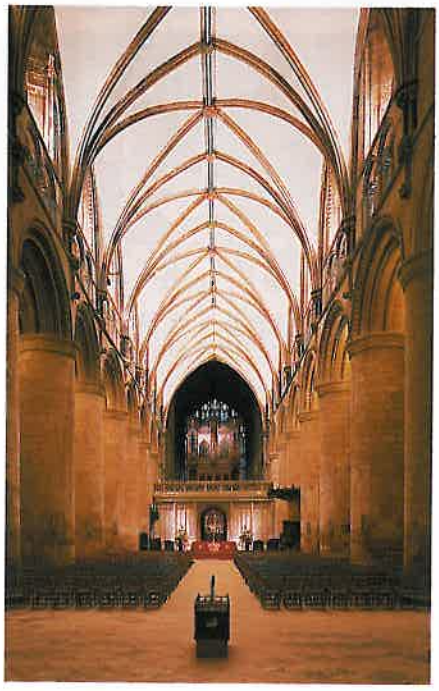
INDIA BUILDINGS

Liverpool

Nearly 100 twin Clipper luminaires using good colour rendering Polylux 2700 fluorescent lamps, hidden from direct view by a specially made pelmet, act as uplights to illuminate the beautifully repainted ceiling as well as providing general lighting. An impression of grandeur is created for the lofty entrance halls which reflects the opulent era of the great merchants. Additionally, the existing decorative tungsten lanterns have been refurbished to utilise two 150W SONDL lamps with the control gear remotely mounted above the ornate ceiling.

Design: G Ander, R W Gregory and Partners
Architect: Holford Associates
Contractor: A and B Engineering





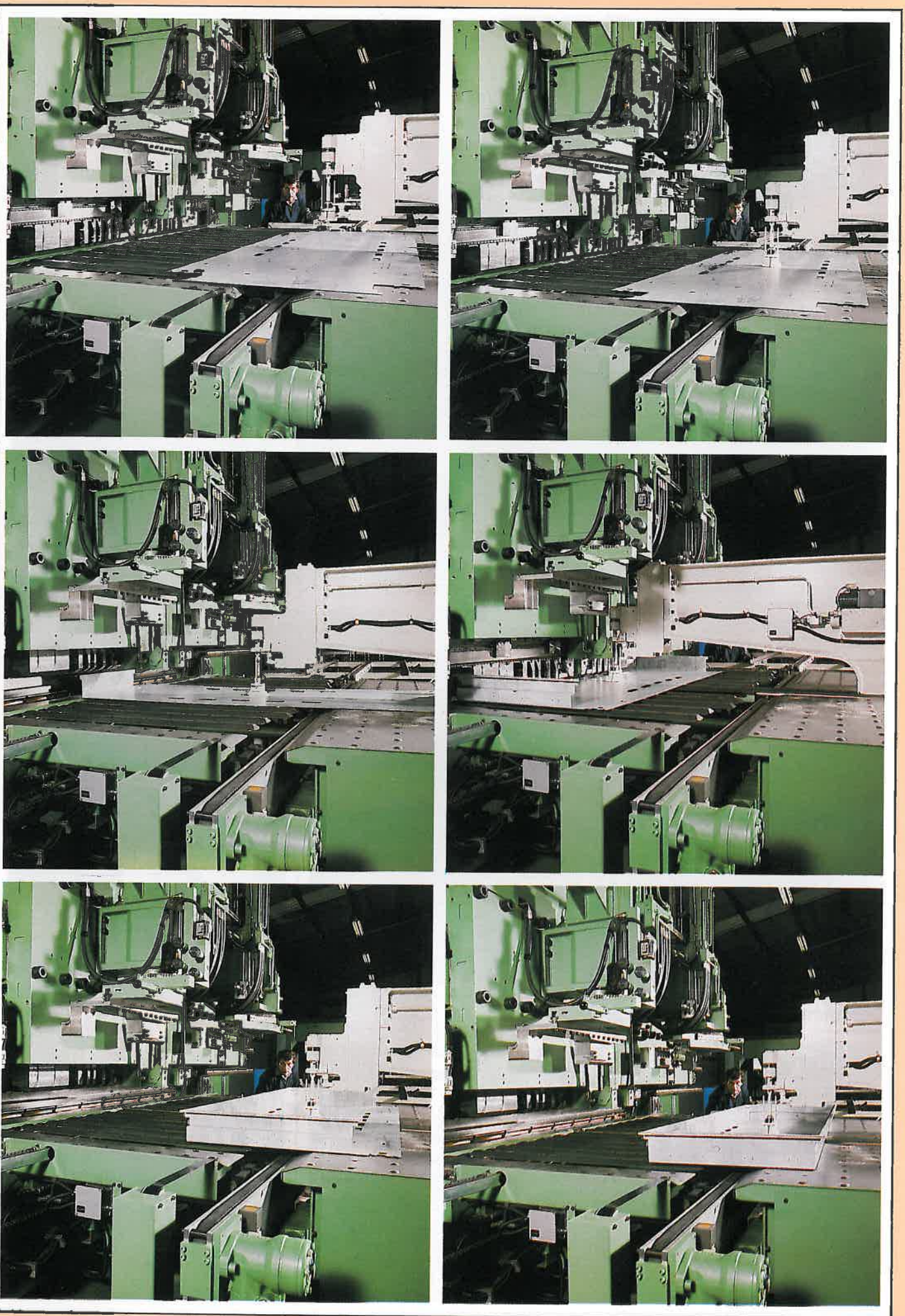
Commended, Civic Section

GLOUCESTER CATHEDRAL

Gloucester

New interior SONDL lighting now allows the Cathedral to be seen in a way never possible when it was originally built. Powerful 400W grp floodlights point upward to light the 13th century vault and highlight the nave's great cylindrical piers, part of Abbot Serlo's original Norman church. More compact 70W Sonpak luminaires are located in the side aisles. All the floodlights are neatly concealed and replace the previous tungsten halogen lighting. Some extra lighting is available via further floodlights mounted on hydraulic brackets, designed by Dowty Engineering, which swing out from the clerestory walkway.

Design:	T Fairhurst, THORN Lighting
Architect:	C B Comely, ASTAM Design Partnership
Contractor:	Mitchells Electrical



CLIVE WHEELER and JOHN PEGG

Investment Brings Customer Benefit

Mr Wheeler is director of Manufacturing and Mr Pegg is director of Technical Development of THORN Lighting at Spennymoor

This year has witnessed the launch of a completely new range of modular recessed fluorescent luminaires for commercial interiors. The Quattro series is a considerable technical advance because of its high performance optics, high frequency electronic control gear, aesthetic value and air handling capability. To the user it offers a product that meets the scope and stringency demanded of lighting in the commercial environment today. Yet Quattro represents considerably more than just another new light fitting. It illustrates the dramatic change in manufacturing methods now taking place that work to benefit both the user as well as the manufacturer. Today's manufacturers are becoming more marketing led, aiming to satisfy customer needs and wants. Through research, innovation, improved production and greater use of high technology, these needs are turned into sales opportunities. Nowhere have these changes been more marked than at the Spennymoor manufacturing complex in County Durham.

MODERN MANUFACTURE

The philosophy of 'just-in-time' manufacture (the factory dispenses with the need for over large stocks of finished goods by quickly producing to customer order), is seeing flexible manufacturing cells supersede the traditional, inflexible production lines. Modern production centres that produce modular luminaires such as Quattro can quickly be switched from one product to another by changing the programme in the controlling computer, achieving the flexibility to produce long or short runs without sacrificing cost efficiency. The obvious benefits translate to the user as product prices are competitively maintained and delivery dates adhered to.

The sequence of pictures on the opposite page shows stages in the production of a Quattro luminaire body. A flat metal pre-cut blank is formed into a luminaire body up to 1800 mm long within 90 seconds.

CAD/CAM SATISFIES MARKET NEEDS

To satisfy an increasingly changing market also demands flexibility in design; somehow the work of the skilled design draughtsman must be speeded up and more use made of previous work. Computer aided draughting satisfies these needs, accelerating design and detailed drawing stages while building up a database which can facilitate future work. Eventually, lighting fitting designers and development engineers will complete the computer aided design and manufacturing (CAD/CAM) chain by feeding design data straight into computer controlled production centres, as the basis for manufacture.

Quattro then signposts the way by combining flexibility, quality and speed in manufacture to produce a wide range of options. The customer benefits because the product design is tightly related to the demands of the market, speedily available and of high performance. Let us then take a closer look at the new style of manufacturing.

SHOP FLOOR FLEXIBILITY

Flexible machining and production cells are becoming commonplace in other industries, but a centre which could punch and form sheet metal into luminaire bodies was not easily found. After much investigation a machine which can pierce, shear, crop and form a flat metal pre-cut blank into a luminaire body up to 1800mm long within 90 seconds was located.

The 'Salvagnini' computer numerically controlled sheet metal production centre has two halves. One half is a machining head which carries out 'punching' and 'nibbling' functions according to instructions held on disc. The computer programme calls up the various tools incorporated in the head, so providing automatic setting up, and determines the sequence of operations to minimise the distance travelled by the sheet as it is manipulated under the fixed head. The other half of the machine hydraulically bends the four sides of a pre-notched sheet, again positioning the material automatically.

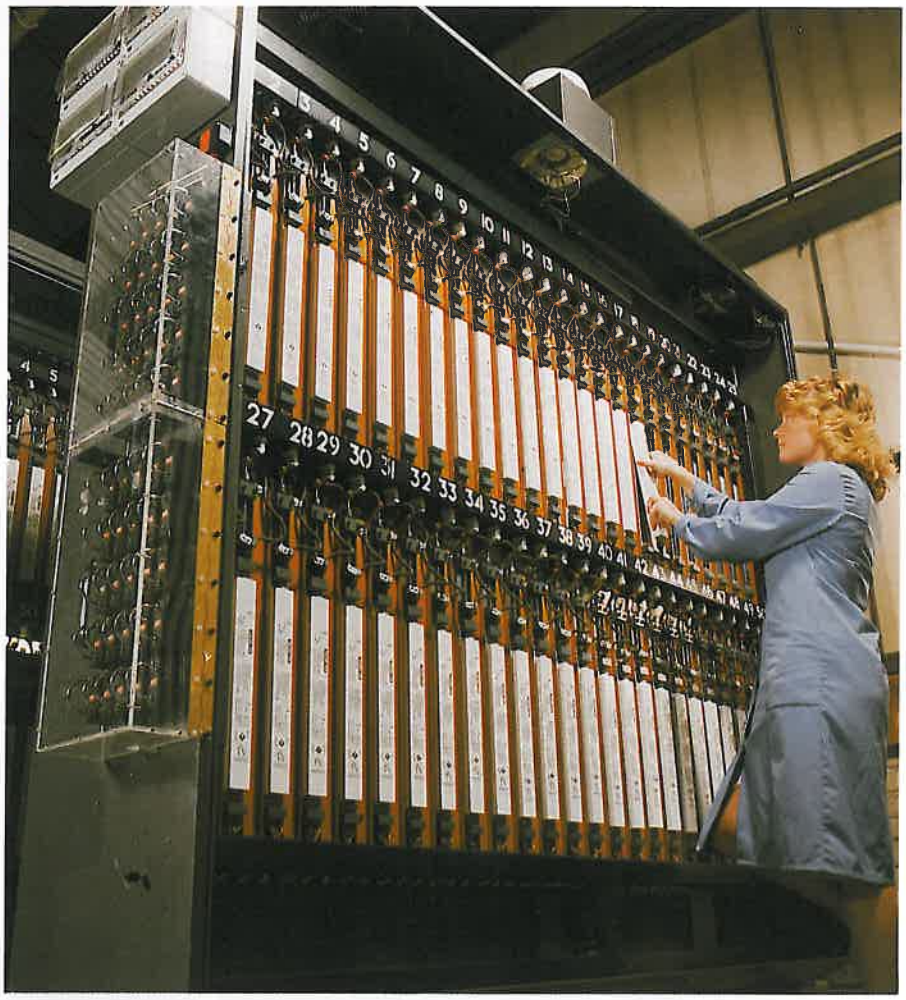
TIME SCALES REDUCED

Such production centres eliminate the need for dedicated special tooling and greatly reduce time scales. Manufacturers can exercise much greater control and flexibility. For instance, a batch of 500 bodies can be produced from one machine in little over a day, compared with weeks when using multiple press brakes with the need for separate setting up for each operation. Sample fittings and follow up orders can be provided fast thus assisting the end user. Such flexibility is invaluable in meeting the growing need for cost-effective, custom-made products with the emphasis on satisfying customer requirements on a shorter time base.

The manufacturing centre is best suited to producing modular fittings, either recessed or surface mounted. The modular body is formed from a single sheet and does not require, in contrast to bodies made on a conventional line, four separate pieces of outer trim spot welded to the body. The machine can quickly turn out pre-production samples – typically one can be produced in a day – compared with two or three weeks for hand prototype manufacture.

FOLLOW UP MACHINES

Since installation in a new purpose-built press shop, follow up machines have been purchased and one of these now produces aluminium louvres from detailed photometric data. Taking the Quattro range again as an example, three types of sophisticated aluminium reflectors are available, tailored to meet the conditions of each individual lighting situation: the bi-planar louvre, the low brightness batwing reflector and VDU batwing ▶



reflector all requiring different permutations of material and form.

The Moulding Shop is another area whose efficiency has benefited from the introduction of new machinery. Injection moulding machines are now microprocessor controlled. When changing moulds, all machine and processing conditions can be loaded within seconds by inserting the appropriate cassette tapes, prepared by planning engineers, into the data carrier. These 350 tonne machines are equipped with robotic 'pick and place' units to lift components from the moulding tool and work 24 hours a day.

A further machine, for assembling starter sockets, automatically cuts contacts from strip, inserts them into mouldings and carries out electrical checks.

ELECTRONICS – GROWING INFLUENCE

The future of the lighting industry is linked with the exploitation of electronics, and at Spennymoor the latest efficient manufacturing methods have been incorporated. The plant can produce a wide range of lighting electronics from discharge ignitors to high frequency electronic ballasts.

Development in the electronic production area has centred on upgrading the production of printed circuits, particularly for the high frequency electronic ballast. Machines automatically select components, test them, insert them into printed circuit boards (PCB) solder the boards and test the finished circuits.

Certain machines are universal in that they accept any axial-lead components from a feed bandolier, and insert them – like a high speed, two-headed stapler – into PCBs in two planes, each board being rotated through 90 degrees when the sequence demands.

A separate sequencing machine selects the components which will be inserted, crops their leads, and tapes them to a bandolier. To keep up with the 20,000 component-per-hour capacity of the auto-insertion machines, the sequencer can prepare several bandolier strips at once. Prepared bandoliers are subjected to off-line computerised quality control checks which provides print out of resistance, capacitance, polarity, continuity and other electrical properties, for each component.

Towards the end of the production cycle PCBs are soldered in a drag soldering machine – boards are 'dragged' over a flux bath and container of molten solder – or in a wave soldering machine. The latter has been acquired to deal with long ballast circuits and the surface mounted devices of the next electronics generation. Circuits finally pass through automatic unit test stations.

Left: **Electronic ballast being inserted into a Quattro luminaire body. The larger picture shows the arrangement of selected high frequency ballasts on quality life testing machinery.**

CAD TRIANGLE

A new look has overtaken the drawing office as computers and keyboards come to three of the Company's establishments – Spennymoor, Enfield and Hereford. A multitude of workstations from Ferranti Infographics have now appeared in the Spennymoor drawing office alone. One of the strengths of CAD is that it reduces tedious routine and 'housekeeping' work, releasing the user's time for more creative activity. The system enables draughtsmen to become more closely identified with the final product.

A carefully planned training programme took draughtsmen to Heriot-Watt University, Edinburgh for an overview, followed by a period of on-site training. Since then the draughtsmen have been using the workstations for draughting in two dimensions and for three- dimensional modelling; assembling on screen 'solid' objects, which the computer can shade in colour for easy visualisation, and construct the view from any direction chosen by the user. The computer produces drawings on screen quickly, ready for printing.

WHAT OF THE FUTURE?

The intention of CAD is that the benefits will be felt far beyond the drawing office to reach the user as higher standards of cost effective engineering are achieved against tight time scales. Eventually, the design process will extend into manufacture, and machines producing parts will be controlled directly from design information.

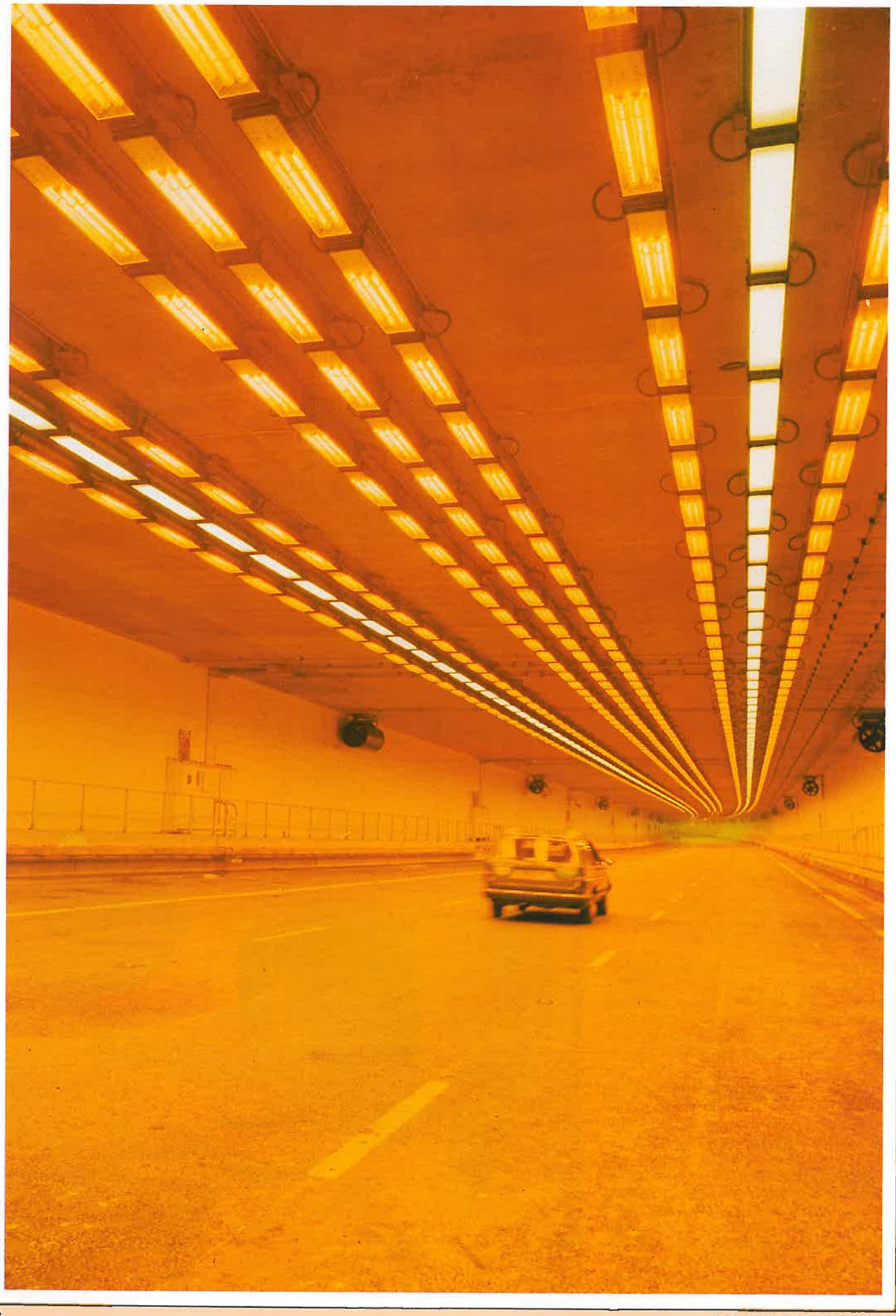
The traditional boundary between design and manufacturing elements will blur as the common database serves to integrate operations. The library of standard parts will also discourage the 'back to the drawing board' syndrome, for each new design, and lead to a positive attitude towards rationalising the range of parts and products.

Above: **Completed Quattro installation at Owen Owen's prestigious Southampton store. The modular recessed luminaires use 2L compact fluorescent lamps with high frequency control gear and low brightness batwing reflectors.**
Below: **Close up of a Computer Aided Design workstation.**

The linking of the factories at Spennymoor, Hereford and Enfield results in greater all-round awareness of new product work and each other's problems, plus less time spent travelling to attend distant meetings.

CONCLUSION

The total picture is one of production and design specialists seeking to combine flexibility, quality and speed in manufacturing. The kind of optimism that new products such as Quattro have already given will certainly keep them going. The most positive aspect is that the resulting increase in productivity and improved delivery will enable the business to react promptly and with greater speed to customer demand. ■



BOB HARGROVES

Tunnel Lighting

In early December 1986 the Duke of Kent opened the Hatfield Tunnel on the A1 Motorway amidst a fanfare of press and TV coverage. "The longest tunnel of its kind in Europe" ran one headline. In fact, Hatfield is the longest high speed tunnel on any motorway in Europe without additional speed restrictions, the speed limit in the tunnel being the same as on the rest of the motorway system. This means that drivers must be able to approach and travel through the tunnel at 70mph with complete and justifiable confidence in their ability to see ahead. If there is the impression of plunging into a black hole then drivers would tend to slacken speed or even brake suddenly so effecting a potential accident situation.

THEORY AND PRACTICE

The major concern with the lighting of road tunnels arises not by night, but by day, as drivers approach the tunnel mouth from bright daylight. There has to be sufficient lighting in the entrance (called the threshold zone) to ensure that drivers have adequate visibility into the tunnel before they enter it. This visibility is achieved at Hatfield by nine rows of luminaires

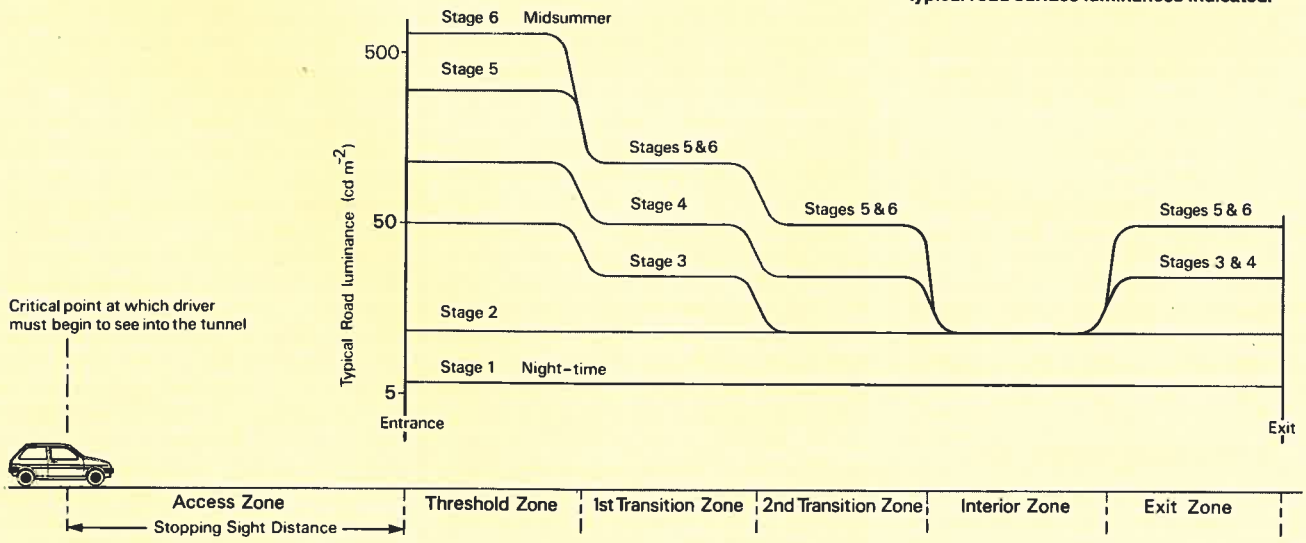
Mr R A Hargroves is a senior section leader of THORN Lighting at Enfield

mounted along the tunnel ceiling in the threshold zone, which at Hatfield is 210m long. Upon entry drivers' eyes will adapt, and so beyond the threshold zone, the lighting level is reduced through transition zones to a minimum 'daytime' level which prevails in the interior of the tunnel. How much lighting should be provided in the threshold zone of a tunnel has been the subject of a considerable amount of research over the last 25 years. The key factor is the brightness of the surroundings to the tunnel entrance (known as the access zone luminance). The access zone luminance is seen by drivers during their approach and is critical when the distance of the car from the entrance is equal to that required by the fastest traffic to stop. This is the point where it is vital that drivers are able to see into the tunnel so that they can still brake safely if necessary. The first stage in a tunnel lighting design is to determine the maximum access zone luminance: this will generally occur at midsummer. The ratio of the luminance of the road surface in the threshold zone of the tunnel to the maximum access zone luminance is important if good visibility is to be maintained. In the new British Standard Code of Practice for Road Lighting, a ratio of 0.07 is proposed for lighting tunnels on motorways and other high speed roads. For roads with less demanding traffic situations, factors of 0.06 or 0.05 are recommended.

OVER 5000 LUMINAIRES INVOLVED

At Hatfield, where the maximum access zone luminance is around 5000 cd/m^2, the road surface in the threshold zone is therefore lit to a luminance of 350 cd/m^2 (5,000 × 0.07). To achieve this, an illuminance of 7,000 lux is produced by nine rows of tunnel luminaires, of which seven rows house 180W low pressure sodium lamps and the other two, twin 65W fluorescent tubes. In fact, a total of 5223 luminaires are installed throughout both bores of the tunnel. The design of the lighting installation took into account a maintenance factor of 0.7. The two rows of fluorescent luminaires continue throughout the tunnel, but the sodium luminaires are phased out through two transition zones up to 420m from the entrance.

Longitudinal section of a motorway tunnel with typical road surface luminances indicated.



Illustrated on page 16 is the impressive interior of Hatfield tunnel. Basic and booster lighting is provided by 5223 luminaires along the tunnels 1150 m length. The former is supplied by twin 65W fluorescent lamps positioned over each nearside and offside lane. The latter is in the form of 180W low pressure sodium lamps situated over each entry and exits and into the tunnel up to the second transition zone.

Fig 1 on this page shows an engineer at Enfield's Jules Thorn Lighting Labs relamping a tunnel luminaire.

At the exit extra rows of sodium luminaires are included to assist drivers who need to overtake immediately upon leaving the tunnel. When they look into their mirrors to see whether the offside lane is clear, the exit zone lighting provides the necessary visibility back into the tunnel.

SWITCHING

The maximum level of lighting in the threshold, transition and exit zones is only required for short periods during the summer months; at other times some of the luminaires will be turned off. The switching takes place in six stages according to the ambient luminance which is monitored by a photometer aimed at the tunnel portals. At night, only one tube in each fluorescent fitting remains alight, giving a maintained illuminance of 100 lux on the road. The automatic switching is set to ensure approximately equal operating hours for each tube.

The light distributions from the luminaires are designed to illuminate not only the road surface to the prescribed luminances, but also the walls as these often provide the background against which other vehicles are seen.

A TESTING ENVIRONMENT

A tunnel environment is a particularly testing one for luminaires: compared with the conventional road lighting lantern, the tunnel luminaire is likely to be operating in a dirtier and more corrosive atmosphere with cleaning by high pressure water jets instead of a sponge and leather. In a three lane motorway tunnel, such as Hatfield, where the lighting has to be mounted over the traffic lanes to cover the road uniformly, the proximity of the luminaires to tall vehicles passing beneath at high speed means that they will be subjected to considerable air buffeting.

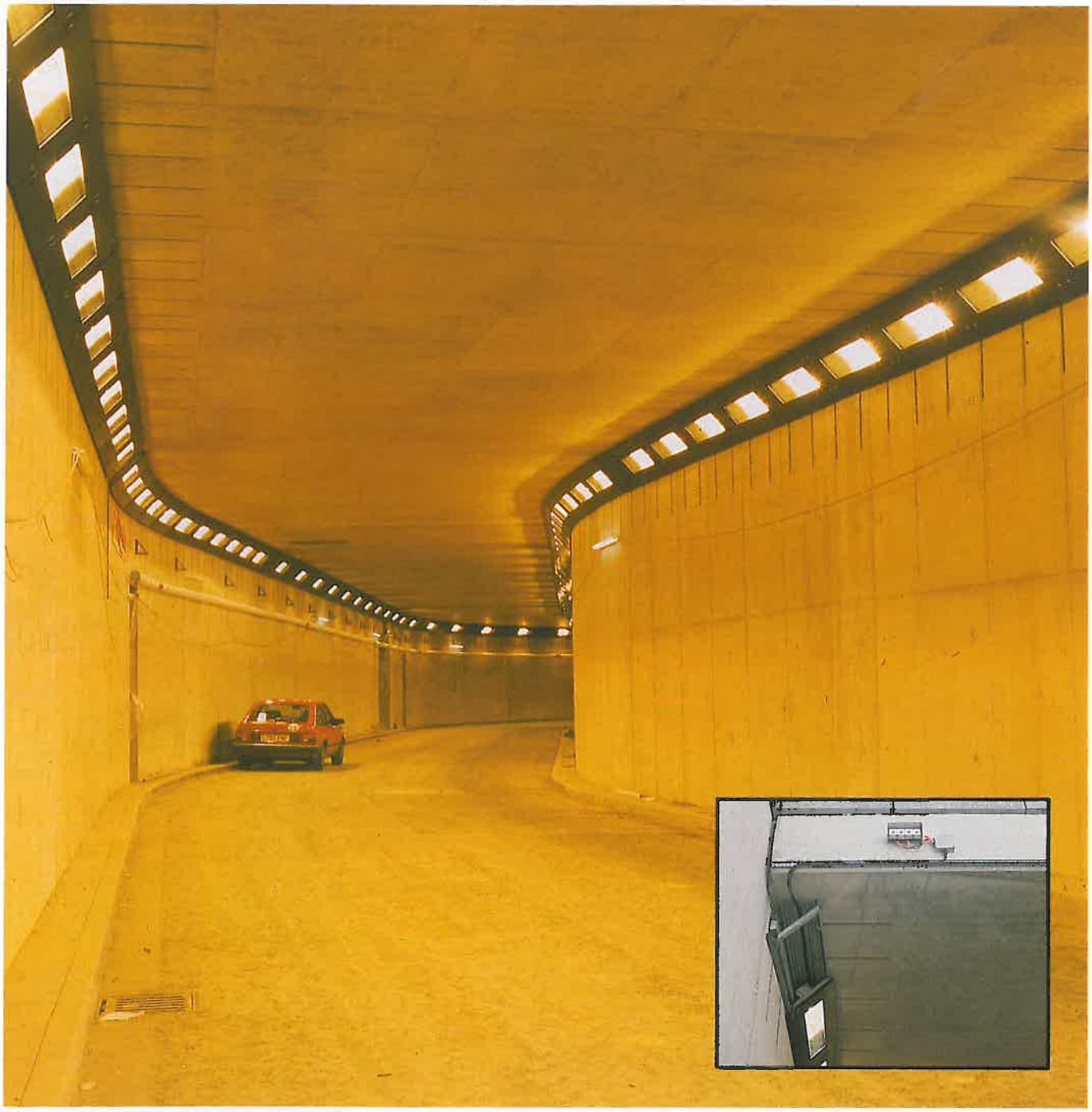
LUMINAIRE CONSTRUCTION

The luminaire adopted for the Hatfield Tunnel has been designed to cope with these conditions. The body is made of 3mm thick extruded aluminium cut to the required length and finished in powdered polyester paint. It incorporates grooves and rails for the accommodation of mounting brackets, control gear, lamps and reflectors, and where neccessary a diffuser or louvres, all of which are slid into the extrusion. The toughened 5mm thick front glass is sealed into a gasket in grooves at the mouth of the extrusion by springing the extrusion apart during production. The glass thus remains undisturbed during the life of the luminaire.

Access to the inside of the luminaire is by means of the end caps which are held tightly against the end gaskets with quick release clips. The advantage of fixed glazing and removable end caps is that the length of mating surfaces is minimised. This means that a high degree of sealing against dirt and water (IP65 rating) can be more easily and reliably obtained and maintained through life. There is also little chance that a sealed front will be damaged by suction effects from tall vehicles which pass below at speed.

MAINTENANCE CONSIDERATIONS

At Hatfield, the luminaires are mounted in continuous rows on the roof of the tunnel, so the mounting brackets are arranged to allow the fittings to be lowered clear of the line for end caps to be removed. The accompanying picture shows how this is achieved: the brackets, of stainless steel, contain three near-vertical slots in which pins from adjoining luminaires can slide. In normal operation they are latched in the upper position. During servicing one or both ends of the luminaire are unlatched and lowered to the bottom of the slots. Removal of one end cap (held captive on a retaining chain) enables the lamps to be changed: this is a simple operation with the lamps being removed and inserted on wire guides. Fig 1 shows this being carried out with fluorescent tubes: in this case the reflector is half withdrawn from the extrusion. The gear tray is mounted above the reflector in the fluorescent version of the luminaire and, at one end adjacent to the reflector in the sodium



version. Lamps and gear are linked by flying leads and connectors so that circuits can be quickly isolated from the supply and, if necessary, reflector assembly and/or gear tray removed for servicing.

CHOICE OF LIGHT SOURCE WIDENS

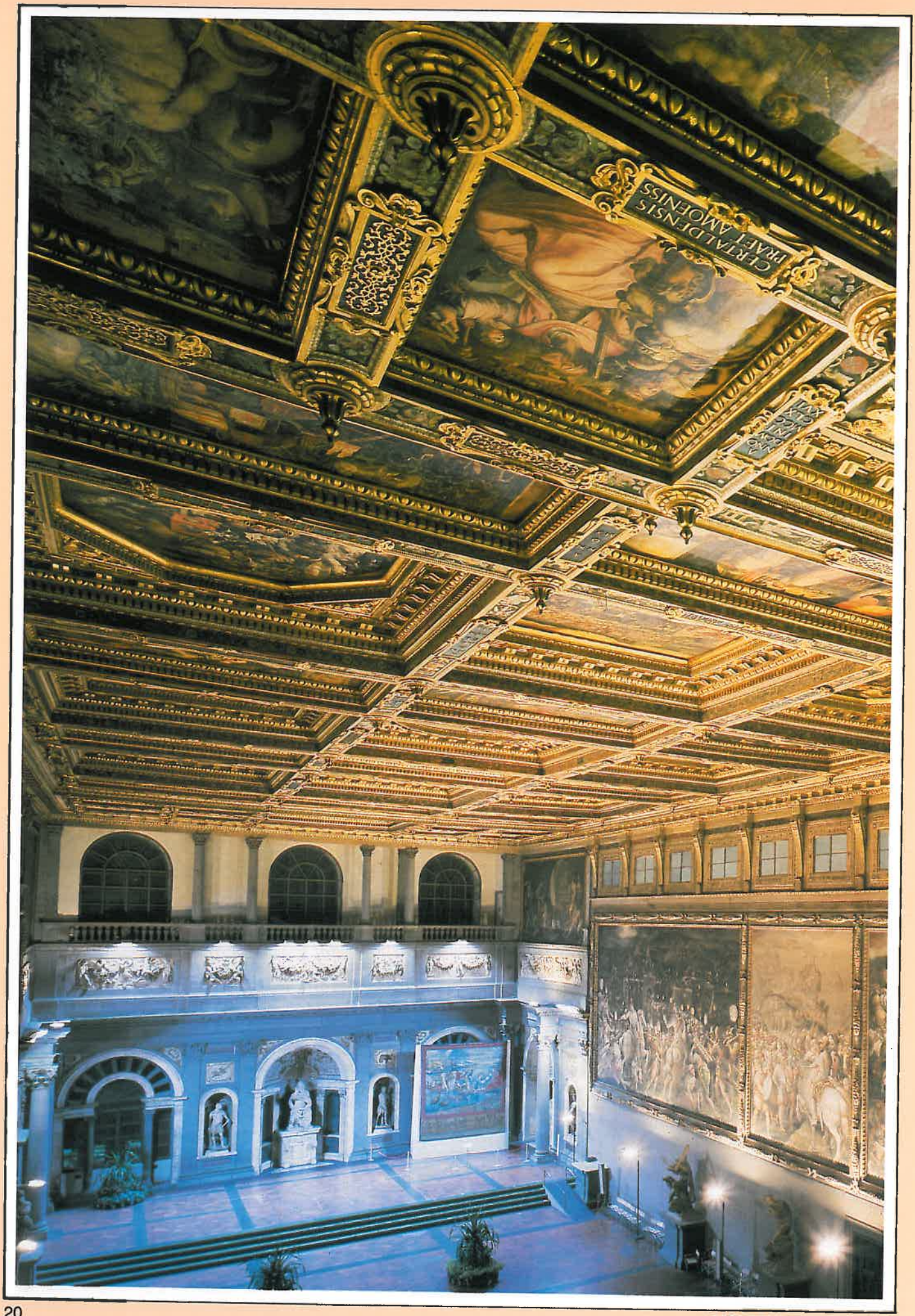
Although Hatfield Tunnel employs fluorescent and low pressure sodium lamps, the tunnel luminaire will also house high pressure sodium lamps. These have the advantages of smaller luminaires for a given light output, longer lamp life leading to longer maintenance intervals and hence fewer road closures, overall operating economics which compare very favourably with the low pressure version, and of course the colour rendering properties of high pressure sodium. For these reasons several tunnels in the new Gatwick air terminal complex have been lit entirely with high pressure sodium luminaires; these are cornice mounted and produce an asymmetric beam distribution to ensure an even luminance over the road surface and walls of the tunnels. The lighting is switched in four stages between the maximum level (3000 lux producing a luminance of 150 cd/m^2) used mainly during the summer and the night time level (150 lux producing a luminance of 6 cd/m^2) where the SON luminaires left alight are in a staggered formation.

More recently the contract for lighting the Penmaenbach Tunnel on the new A55 road along the scenic North Wales coast has been obtained. Work will commence this year on the installation of SON-T and fluorescent (electronic ballast) tunnel luminaires.

Above may be seen a general view of the new North Terminal site tunnel at Gatwick Airport which uses 227 cornice mounted luminaires with 250W SONDL-T lamps. Inset is the lighting control system from ECS.

CONCLUDING THOUGHTS

The use of tunnels in road construction has traditionally been limited to negotiating hilly terrain and traversing rivers. Now, however, they are becoming increasingly popular owing to the demands for complex road junctions, quick, direct travel and for complying with environmental constraints. We are today equipped with better tunnel lighting products to meet these needs than ever before in terms of high efficacy, durability and economy of performance.


CERTALDENSIS
PRAETI AMOENISS

Thoroughly International

A company which has subsidiaries in 14 countries, is active in 140, and has full scale manufacturing plants in eight, could fairly be described as thoroughly international.

For THORN Lighting, with its headquarters in the U.K., the overseas market has been big business for nearly 40 years – to the point where overseas sales now contribute virtually 60 per cent of the Company's total turnover. During these years a comprehensive lighting solutions advisory service for customers has been provided throughout the world. This article which briefly outlines the international business operation is emphasised with reports of installations as far north as Melville Island, northern Canada and south as Sydney, Australia.

Global business depends vitally on being seen to be active in the territories concerned; consequently the degree of serious intent of a company can be gauged from the strength of its presence, indigenous manufacturing being by far the most visible sign of its commitment. To meet the demands of Europe there are major factories in the U.K., Germany, Sweden, Finland and Italy. Further afield, New Zealand, Australia and South Africa manufacture high technology lighting equipment for their home market. In fact, even China is now producing discharge lamps as a result of a technology transfer agreement under which the country has set up its own manufacturing plant.

Florence Town Hall, opposite, where the contrast of the light sources creates a pleasing atmosphere.
High pressure sodium floodlights at work in the North West Territories of Canada.

WESTERN EUROPE

The European lighting market is worth some £2.4 billion per year with the most significant territories being West Germany and the United Kingdom.

The U.K. operation is sufficiently well known not to need detailed discussion here. Suffice it to say that factories at Enfield, Leicester, Hereford, Spennymoor in County Durham, Preston and Merthyr Tydfil manufacture one of the most comprehensive and varied product ranges in the industry. A selection of notable U.K. installations is detailed under the National Lighting Awards article – see page 8.

THORN Lighting has been operational at Neheim-Husten near Dortmund since 1957. The operation now produces energy efficient lighting systems which combine fittings and high technology light sources.Recent product development work has centred on compact fluorescent, low voltage tungsten halogen and low brightness fluorescent luminaires.

A similar product orientation exists in Italy where SIVI Illuminazione SpA has a factory at Vicenza, near Milan. A treasure trove of superb architecture and painted interiors, Italy offers wide opportunities in the floodlighting market. For instance the centre piece of Palazzo Vecchio, Florence's Town Hall, is the Salone dei Cinquento (Hall of the 500). This has recently been lit using 10 area floodlights in uplight mode, with

Above: **Baltiska Hall, Malmo, Sweden using deluxe high pressure sodium luminaires and, below the dramatic floodlighting of the Rock of Castel, County Tipperary, Ireland.**

400W de luxe high pressure sodium lamps, and thirteen 250W floodlights with metal halide lamps. The luminaires highlight to stunning effect the magnificent ceiling of frescoes and wood carvings. The wall frescoes are the work of the painter Vasari and the victory statue is by Michelangelo.

In Sweden an existing agency was taken over in 1963, and THORN Belysning AB bought its own factory ten years later. It now produces a strong range of products from floodlights to industrial discharge fittings and uplights. A similarly wide range is marketed in Finland, Denmark and Norway, with compact fluorescent and low volt tungsten halogen now adding a new dimension to activities. The recent acquisition of the Järnkonst Group has greatly strengthened the business. The Scandinavian operation successfully tackles many interesting lighting projects each year. Illustrated is the Baltiska Hall in Malmo lit with de luxe high pres-

sure sodium lamps while the compact fluorescent 2D light source recently formed the bases of a contract to light the head office of Scandinavian Airlines (SAS) in Stockholm. It is interesting to note that Järnkonst is providing all exterior floodlighting and amenity lighting for the SAS project.

Elsewhere on the continent are further extensive commercial facilities. THORN Eclairage, based near Lyon markets a wide range of lamps and fittings throughout France. One recent, notable installation is the use of the high pressure sodium lamp to light the main roads of Marseilles. High technology products are also finding ready acceptance in Ireland, where operations began in 1968. One such example is the Dun Laoghaire shopping centre near Dublin recently refurbished with some 1200 compact fluorescent 2D luminaires, installed within the open-cell ceiling, together with 350 low voltage tungsten halogen downlights. Floodlighting also maintains a high profile and a spectacular example of this is the illumination of the Rock of Castel in County Tipperary. Seat of the early Kings of Munster, ancient is blended with modern in the form of low pressure sodium and mercury lamps. Finally THORN Licht in Austria has also been operating since 1968 concentrating more recently on specification work.

U.S.A.

The American lighting market is the biggest in the world with the industrial and commercial sectors alone generating a demand for £2.75 billion of equipment per year. THORN Lighting has an operation in Canada and also deals successfully in the high technology American lighting market.

Particularly prestigious projects include major sports stadia such as Shea Stadium in New York, Chicago Soldier Fields and the Hubert H Humphrey Metrodome in Minneapolis. More recently the 72,000 seater Miami Dolphin Stadium in Florida has been lit with 440 1kW hot restrike compact source iodide (CSI) floodlights providing ample illumination, good beam control and excellent colour rendering.

PACIFIC BASIN

There are similar opportunities and activities in the Pacific basin. Since the 1950s THORN has been present in New Zealand and since the 1960s in Australia. A manufacturing site and regional offices represent the business in each country nationwide. New Zealand regards low voltage, security and amenity lighting along with floodlighting as growth areas in the operation's future. In Australia the emphasis is on commercial and industrial products, together with opportunities in floodlighting.The Ferry Quay in front of Sydney Harbour illustrates the skill

Shown above are two applications of deluxe high pressure sodium lamps. The upper left-hand picture is of Marseilles, France and to the right the workshop of Alcoa at Pinjarra in West Australia where 186 400W high bay fittings provide a 500 lux illumination. Shown below is the Dun Laoghaire shopping centre lit with 2D compact fluorescents. Inset is a close up of the fittings.

necessary in a major floodlighting installation. Here a 36 bank of CSI lamps is mounted on a light weight tubular aluminium headframe which can be detached from the crane in under 10 minutes.

AGENCY PRIDE

Subsidiaries in local markets have the advantage that the needs and preferences of a particular market can be met precisely. A large measure of autonomy is left to local management. Nevertheless, since it is not practical to be based in all territories, international business depends on having a strong agent/distributor. Franchise holders are nutured carefully and particular pride is taken in the network which has been methodically built up over the years.

Because enormous pains are taken to seek out and appoint compatible agents/distributors who will maintain the standards of professionalism and customer service, the network is highly stable. Though network surgery is occasionally necessary the average agency tenure is in excess of ten years. A few select agents, like G.Th Pierides and Son in Cyprus and Falma Gluhlampenfabrik in Switzerland, have been in from the start, appointed some 40 and 30 years ago respectively.

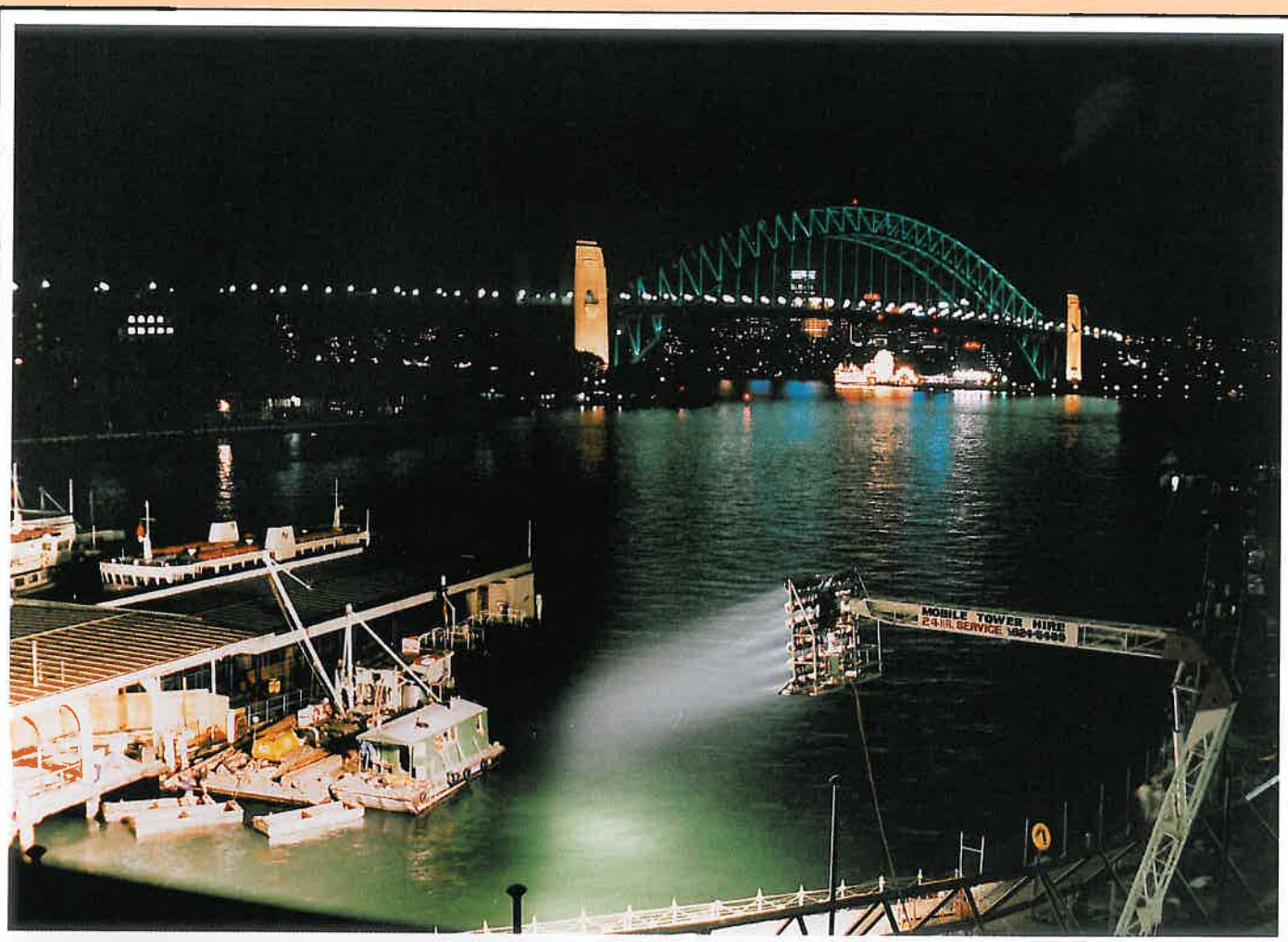
Moreover representation in the territories is backed up by sales staff at the International Division's headquarters at Romford, U.K. Specific executives represent Central, East and West Africa, the Middle East and the Far East. The Company is also present in the Americas and the Caribbean.

In Hong Kong, sole agent Jardine Engineering has run successful campaigns for energy saving lighting helping compact fluorescent make its mark in China. In two recent installations 16W and 28W 2D luminaires light the World Trade Centre and a new office complex in the city of Guangzhov.

Schemes can be extensive. An irrigation project in Libya required a quarter of a million pounds worth of fluorescent fittings to light pumping stations and other buildings. Other equipment, including floodlight and high bay fittings, were also specified. Over 10,000 special recessed fluorescent fittings equipped a large office area on the waterfront of Wanchi, Hong Kong. Also in Hong Kong design skills are illustrated in lighting the Supreme Court, one of the few original buildings left, creating attractive effects with metal halide lamps inside and the 'warmer' de luxe high pressure sodium outside Exchange Square, Jubilee sports

Above: **Zimbabwe's National Stadium at Harare. A total of 816 floodlights have been installed housing 1500W MBIL lamps.**

Below: **Floodlighting at the Municipality Planning Building in Abu Dhabi, supplied in conjunction with local agents in the United Arab Emirates, the Ranya Contracting Company.**



The high level of illuminance achieved at Ferry Quay, Sydney, Australia is clearly illustrated by the above photograph.

The picture below shows 2D luminaires at Maxims restaurant in Hong Kong.

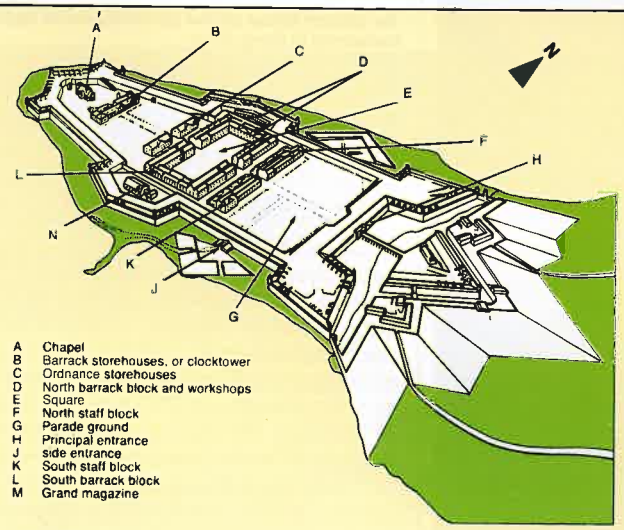
ground, the Coliseum and Maxims restaurant are yet further Hong Kong applications successfully completed.

The International Division can sometimes maximise its contribution by working directly with the public sector. When Malaysia decided to upgrade all road lighting, replacing existing mercury lanterns with high pressure sodium some 22,000 lanterns were supplied from the Hereford factory in the U.K. Likewise a further 17,000 fittings have recently been ordered for local municipal boroughs in Cyprus.

ENGINEERING SERVICE

Lighting today is a complex technical subject and customers value highly a sound engineering service to help with scheme design. In addition to each subsidiaries lighting engineering department is the International Project Engineering (IPE) service based at Romford. IPE began as an operation to support the commercial department but now spearheads sales through its own technical competence preferring to be involved from the start of a project and helping contain budgets by contributing at the specification stage. An example of how IPE can be involved throughout a project is illustrated by major stadium installations at Harare in Zimbabwe and Kasarani in Kenya. These stadiums have been lit with 816 and 588 1500W metal halide floodlights respectively.

Other examples of lighting schemes shown in the illustrations serve to indicate further the scope of THORN Lighting's contribution to providing lighting solutions internationally.



A Chapel
B Barrack storehouses, or clocktower
C Ordnance storehouses
D North barrack block and workshops
E Square
F North staff block
G Parade ground
H Principal entrance
J side entrance
K South staff block
L South barrack block
M Grand magazine

Fort George was planned in 1747 by William Skinner (Director of Engineers for North Britain), and took 22 years to complete, using the experience as builders and architects of the Adams family.

Situated on an isolated spit of land 19 km north-east of Inverness, by the village of Ardersier, it provided a strategically important and impregnable base for George II's army, replacing an earlier fortification on the site of Inverness Castle. It was to employ all the principles of fortification perfected throughout Europe by the celebrated French engineer, Marshall Sebastien de Vaubaun.

These bastioned defences, with all their outworkings, are intact today. It is believed to be the largest fort in the world, covering about 17.4 ha, and has remained in operational use virtually since construction, with very little alteration. Within the fortified ramparts, which feature "casemates" (bomb-proof shelters) is a range of symmetrically planned internal buildings on a monumental scale with plenty of open spaces.

The north and south staff blocks make an imposing facade to the west of the parade ground. The south block features the governor's house (now an officers' mess) with its attractive pediment and portico, while the north block accommodated the lieutenant-general and fort major. Further west are the two main barracks (which housed 1600 infantry) facing inward onto the barrack square, while the workshops and grand magazine store are situated to the north and south respectively.

Twin ordnance stores, a bakery and brewhouse (also known as the Clocktower block) and chapel complete the major buildings.

Fort George — The Rehabilitation of an 18th Century Artillery Fort

Fort George, near Ardersier, Inverness is one of the outstanding artillery forts in Europe and a classic example of surviving 18th century military architecture. Its rehabilitation programme, to house a modern infantry battalion, under the direction of the PSA/DOE Directorate of Scottish Services on behalf of the Ministry of Defence, has taken three years.

The project required the installation of some 4,500 luminaires, 13km of mains cabling, 210km of branch circuit wiring and 18km of conduit and mics/pvc cable.

ELECTRICAL SERVICES AND CONTROL

The key features of the refurbishment were the need to implement major changes in keeping with the architecture as Fort George is a grade 'A' listed building in the care of the Scottish Development Department, Historic Buildings and Monuments (HB&M) section, and to maintain a tight 26 month deadline.

The construction of new roads, drainage and water services, enabled the replacement of the electrical distribution system and the opportunity was taken to remove from view electrical feeder pillars (originally exposed on the battlements) and relocate the incoming supply to a more central position. This reduced voltage drop and established discharge lighting as a practical proposition. Maximum demand load is similar to the original installation, in the order of 620kVA and the overall power factor being better than 0.95 lag.

The army requirement for security of supply was met by providing standby generators. A non-standard control solution was adopted for the Fort generator as the only suitable location for a generator room was remote from the main switchroom, close to a source of oil supply. The scheme involved mains monitoring at the intake point and interlocked contactors, each operating an acb on the main switchboard and an essential switchboard adjacent to the generator. This permitted cabling to be used for both ways operation, the main switchboard being backfed under standby conditions.

Various items of mechanical plant, including sewage pumps and treatment equipment, required to relay alarm signals to a central point. To avoid the use of additional control cables mains cable transmission techniques were employed. This arrangement was also used for remote switching of road lighting and load shedding of non-essential power services in isolated locations up to 1km from the Fort. ▶

On the opposite page is the principal entrance lit with special 70W SON uplights while at the foot of the page can be seen the westernmost ramparts, some 500m away.

THE LIGHTING SPECIFICATION

Criteria for exterior lighting were:

1. To keep lighting in sympathy with the Ancient Monument. To be unobtrusive during daylight (preferably mounted on existing buildings) and complementary to the appearance of the buildings during darkness.
2. Make use of the existing distribution system.
3. Improve lamp life and uniformity of illumination for security purposes.
4. Provide central control.
5. Reduce the electrical load.

The existing lighting scheme installed in 1972 comprised 15 building or wall mounted 2000W linear tungsten halogen lamps in enclosed floodlights, twenty-five 500W tungsten halogen lamps in open-fronted reflectors and a few 100W tungsten Wellglasses. All lighting was sourced from local distribution equipment within individual buildings with a hard wired control system back to a spring reserve time clock in the headquarters office.

The lighting was susceptible to continuous maintenance problems caused by severe winds and the proximity to the sea aggravated the situation further by quickly deteriorating the open reflectors. Average lamp life was a mere 400 to 700 hours.

After extensive site trials using various high intensity discharge light sources high pressure sodium (SON) was selected as best meeting the design brief. Advantages included enhancement of building appearance during darkness, increased lamp life, substantially reduced power consumption for similar light output, and robust and unobtrusive luminaires.

To improve uniformity, the number of luminaires utilised was increased from 40 to 117 and the opportunity taken to enhance the environment by lighting architecturally interesting areas. These included: the chapel, the grand magazine yard and facades, the north and south staff block piazzas, the principal entrance facade and tunnel and the clocktower underpass.

The floodlighting presented a number of problems, not least the fixed location of the floodlights which required great resourcefulness. Extreme care and attention was needed to ensure that the new equipment blended in with the architecture. The authorities at Fort George were very conscious of this point throughout the project and concealment of equipment was a must.

To ensure correct scale in relation to building heights it was decided to use building mounted 400W and 250W SON-TD lamps in enclosed floodlights at eaves level, with control gear remote mounted within roof voids for easy maintenance. Where floodlights were located on perimeter rampart curtain walls the control gear was mounted below the lantern while other gear boxes were recessed into the ground. The switch from tungsten halogen to SON resulted in substantial benefits. For example, for the 5400m^2 barracks square, four 400W and 250W SON-TD floods replaced eight 2000W tungsten

Opposite is the plain 1763 chapel dramatically floodlit to ensure maximum modelling. Above is the barrack square, as with other open areas lit with SON-TD lamps of 250 and 400W, while below is a further view of the tunnel entrance. The switch from tungsten halogen to high pressure sodium resulted in substantial benefits. Electrical load was reduced and service illuminance increased.

halogen units. Electrical load was reduced from 16 to 2.85kW while service illuminance rose from 15 to 25 lux, a noticeable improvement.

Careful siting of the floodlights illuminating the plain 1763 chapel has ensured maximum modelling because, even when one is standing behind a floodlight, there is another to the side producing some shadowing. The floods highlight to great effect the front of the polygonal chancel, the western tower with battlements and both rounded stair wings.

The existing twenty five 500W tungsten halogen floods placed on curtain walls of between 2.5 and 5 metres high were also replaced by SON luminaires, in this instance with 70W wall bulkheads. This arrangement allowed maximum use of existing cabling with relatively minor extensions and more importantly little disturbance to existing grassed areas over the ramparts and bastions.

The principal entrance and tunnel area is of particular architectural interest and the lighting required total sympathy with the structure. The client desired that the luminaires should not be of pseudo-Georgian design but reflect the present day. The barrel vaulted tunnel was considered to be of such architectural merit that lighting was not to be introduced.

Equally, the users required the entrance way to be lit for military traffic and security purposes.

Lighting was therefore introduced via 50W SON marine bulkheads mounted vertically in door ingos at each end of the tunnel and these provided more than sufficient illumination ▶

for safe passage. The collonade in front of the tunnel required illumination and this was achieved with ingenious 70W SON-T uplights of slim dimensions to suit column head banding and finished to match the cream sandstone. These specially manufactured uplights also light the 'piazza' areas within the two staff blocks, facing this entrance.

In total the new lighting scheme has resulted in a 43 per cent reduction in load from 42.5 to 24kW, a 250 per cent increase in lumen output and a fivefold increase in uniformity and distribution. Lamp life has been substantially improved resulting in greatly reduced maintenance costs.

The users required to control and monitor a number of different systems throughout the site in each building and it was therefore decided to utilise the derived control scheme to control the external area lighting also. The solution gave time clock and on/off override control and system status at the users' selected points. This arrangement avoided the need for vast amounts of control cabling running between each building.

All the building interiors have been revamped and lit to high standards and where possible lighting design has been based on 1800mm 70W fluorescent luminaires using Pluslux 3500K lamps and on 16W and 28W 2D lamps in circular luminaires. Bulkhead luminaires using 8W fluorescent lamps light duct spaces and provide essential emergency lighting, while power hungry tungsten has been restricted to the museum and for chandeliers and bedlights. Two interior areas are worthy of special mention.

Firstly, the junior ranks' mess posed problems as in the dining area natural light is restricted to five circular high level windows. A service illuminance of 500 lux has been achieved, making full use of the architect's intention to create a stepped ceiling, by carefully introducing 32 recessed single fluorescent luminaires with prismatic attachments. Efficiency is 61 lux per W/m^2.

Secondly, the servery and kitchen area, constructed from the original walled yard behind the building. As this wall had to be retained except for essential doors, the architects arranged all natural lighting via three longitudinal roof lights which run from end to end of the area. Artificial lighting in the form of fluorescents is provided by continuous perimeter pelmet lighting; recessed modular luminaires over the servery area, where a flat soffit

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On the facing page recessed fluorescent luminaires with prismatic attachments were used to light the junior rank's mess. *Above:* **The kitchen and serving areas also have fluorescent lighting throughout, some IP65 rated. Below is an alternative view of the chapel with SON floodlights picking out the unusual chancel.**

exists; and IP65 rated proof luminaires, some located within segmented stainless steel canopies.

Power services within the kitchen terminate, in local stainless steel rccb/mcb distribution units, at each equipment island and servery counter range. There are central pedestal-mounted stainless steel trunking runs with power services terminating in a 13A switch socket or a BS4343 de-contactor socket for heavy single and three phase loads.

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